US009327815B2

(12) **United States Patent**
Uenoyama et al.

(10) **Patent No.: US 9,327,815 B2**

(45) **Date of Patent: May 3, 2016**

(54) **OUTBOARD MOTOR**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/525,242**

(22) Filed: **Oct. 28, 2014**

(65) **Prior Publication Data**

US 2015/0239544 A1 Aug. 27, 2015

(30) **Foreign Application Priority Data**

Feb. 27, 2014 (JP) 2014-036837

(51) **Int. Cl.**
B63H 20/14 (2006.01)
B63H 20/20 (2006.01)
B63J 99/00 (2009.01)

(52) **U.S. Cl.**
CPC ***B63H 20/20*** (2013.01); ***B63J 99/00*** (2013.01); *B63J 2099/006* (2013.01)

(58) **Field of Classification Search**
CPC B63H 20/20; B63H 20/30; B63H 20/32
USPC 440/75
See application file for complete search history.

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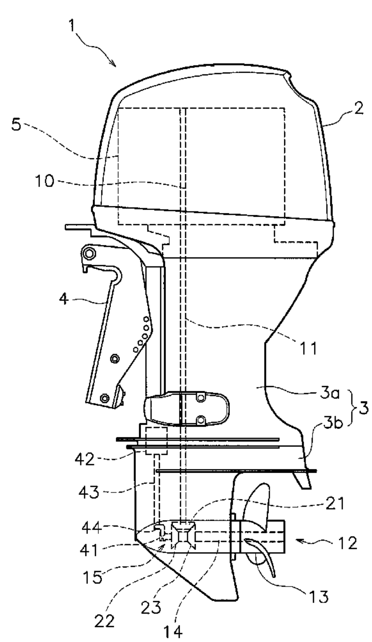
(74) *Attorney, Agent, or Firm* — Keating and Bennett, LLP

(57) **ABSTRACT**

A dog clutch selectively meshes with a forward gear and a reverse gear according to an operation of a shift operating member such that connection of the forward gear or the reverse gear to a propeller shaft is changed. A friction clutch transmits the rotation of a drive shaft to the propeller shaft by a first friction surface and a second friction surface contacting together. Before a shifting stage in which the dog clutch meshes with the forward gear or with the reverse gear, a control unit is configured or programmed to control an actuator so as to execute synchronization control by making the first friction surface and the second friction surface of the friction clutch contact one another.

10 Claims, 14 Drawing Sheets



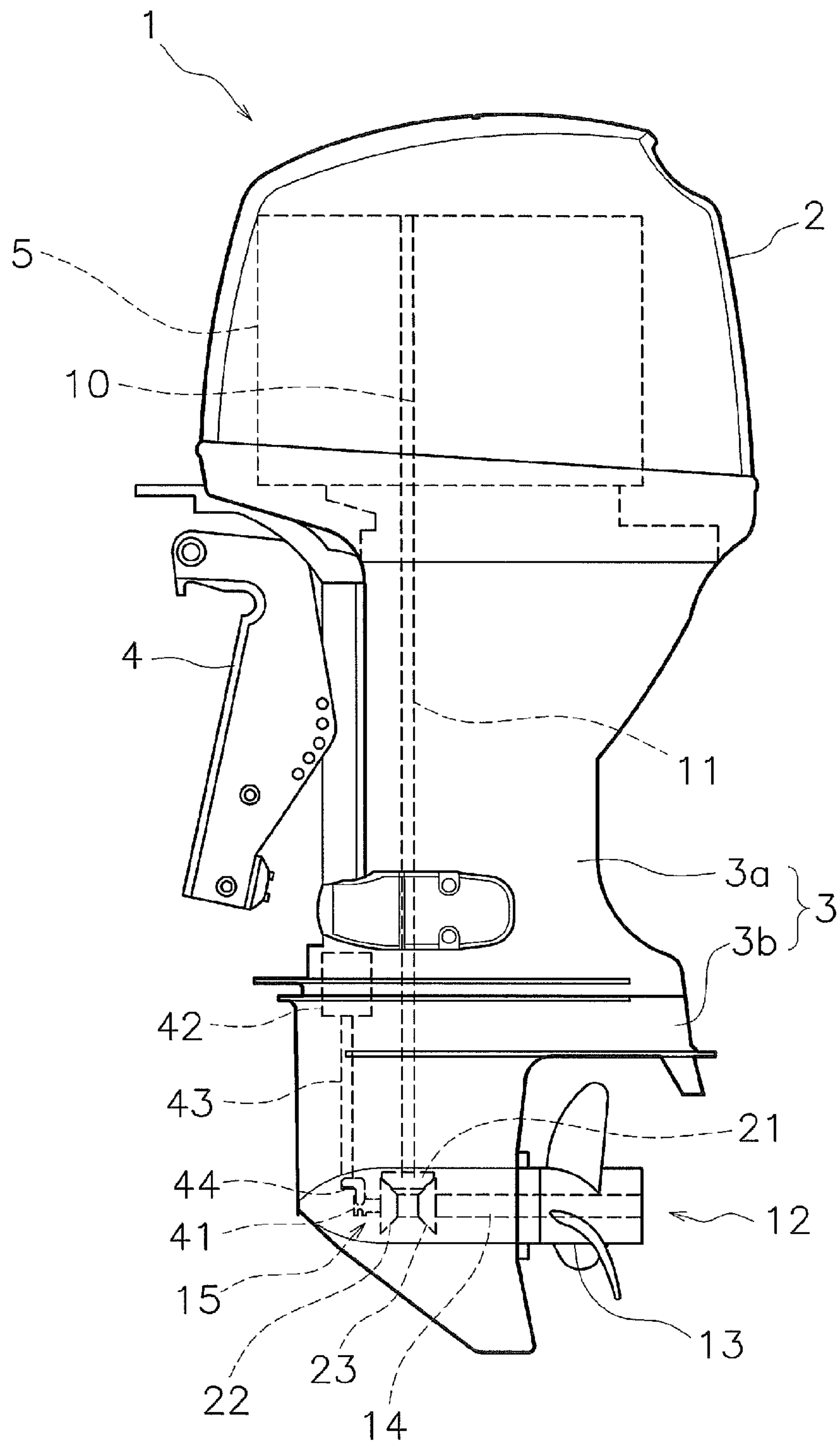


FIG. 1

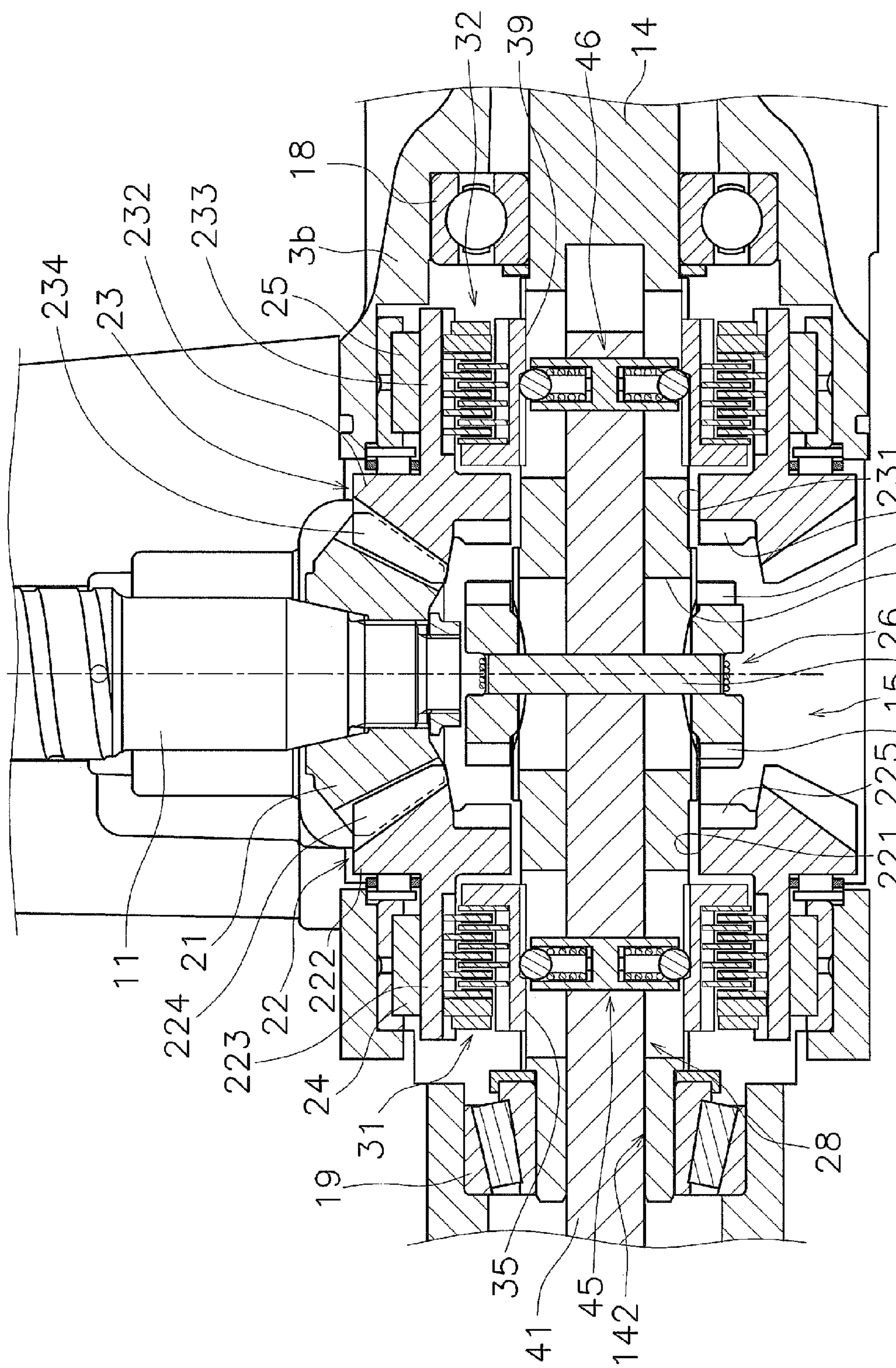

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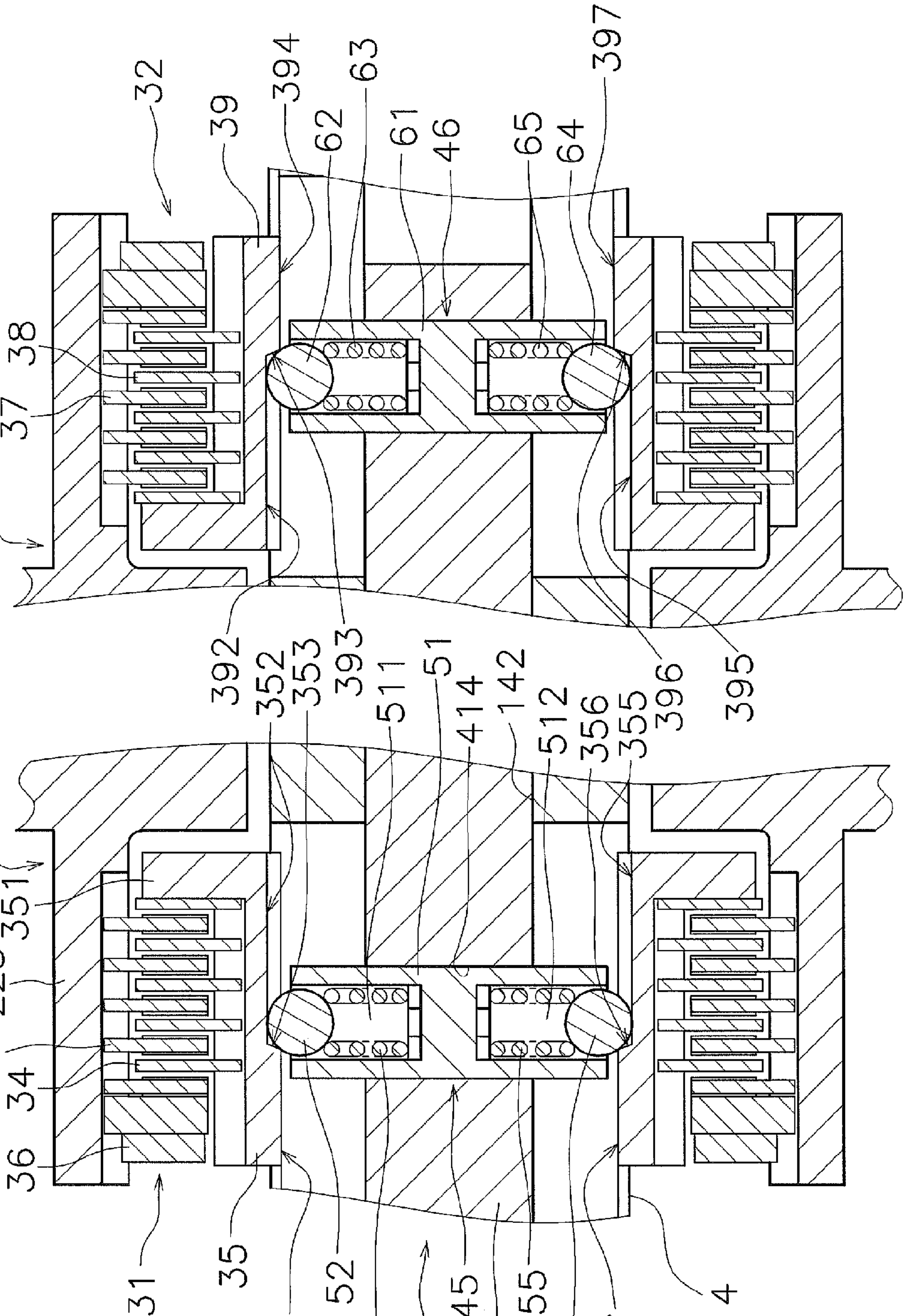
FIG. 2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355
396
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357
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FIG. 3

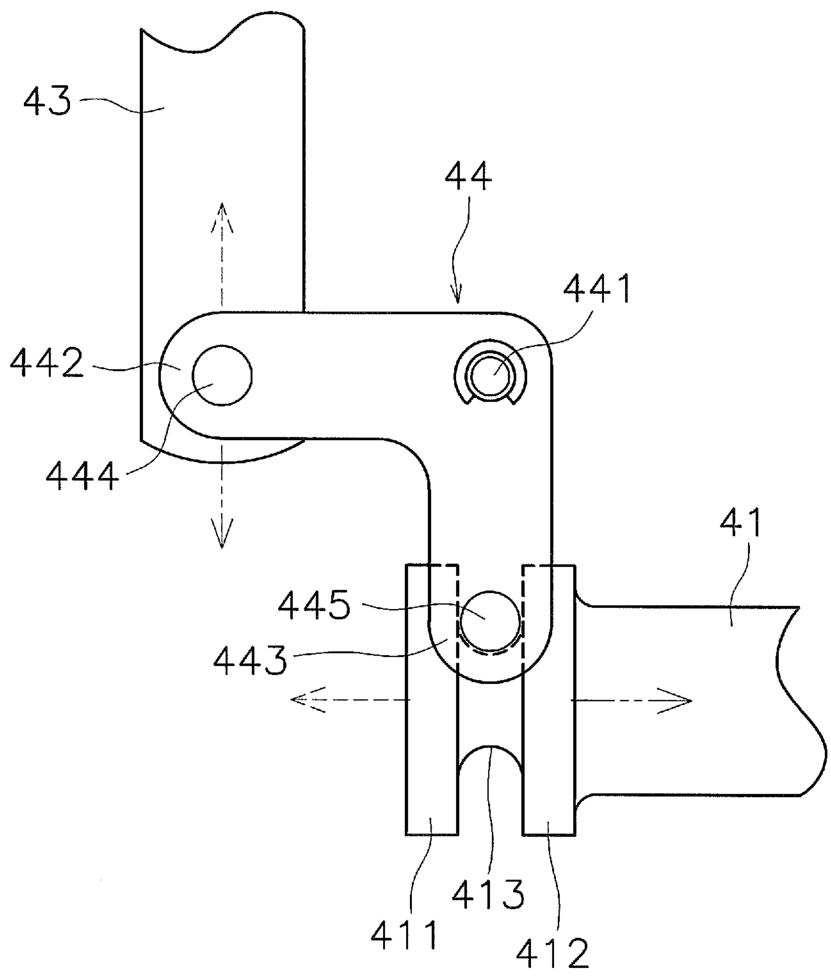

FIG. 4

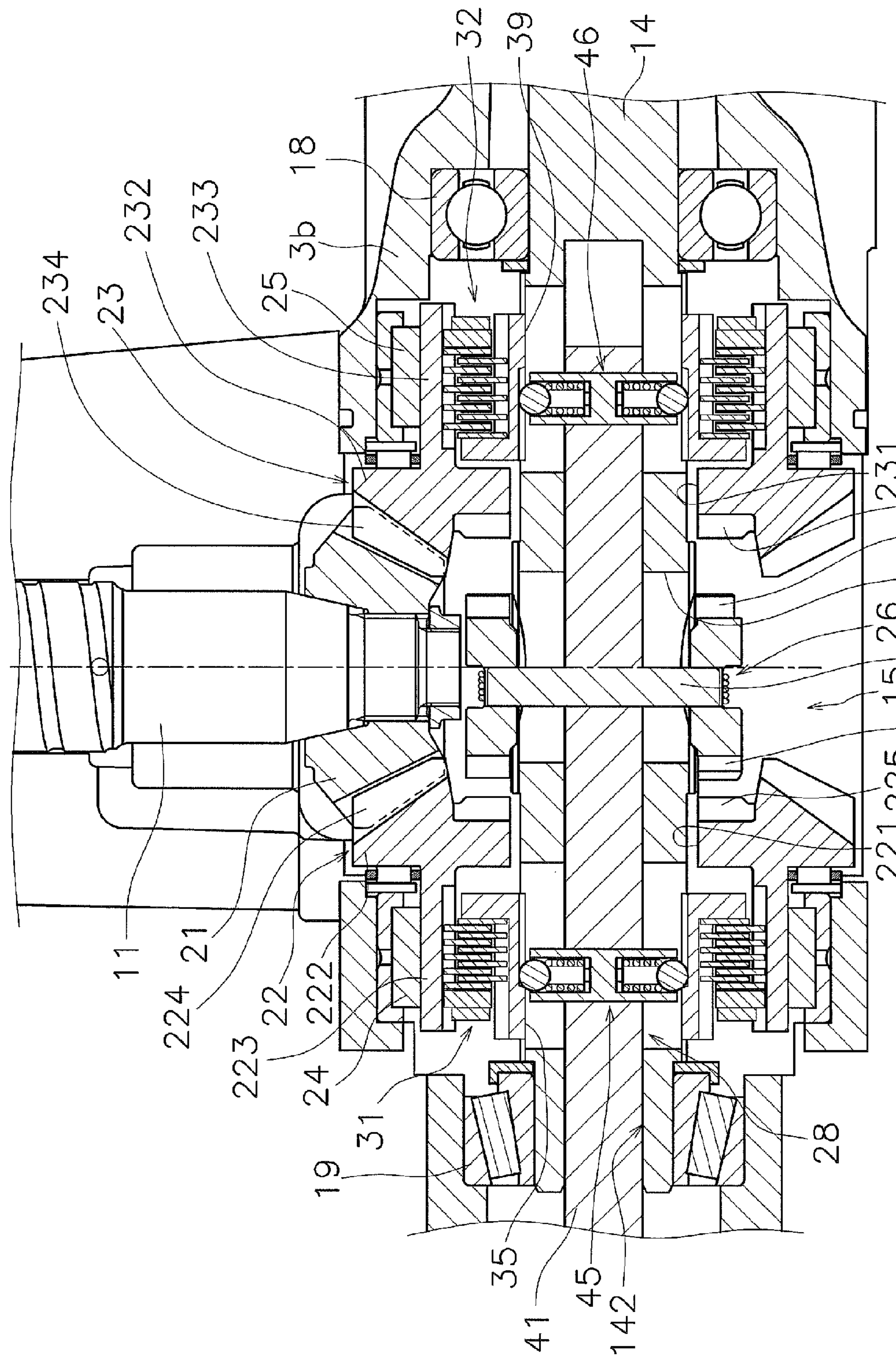
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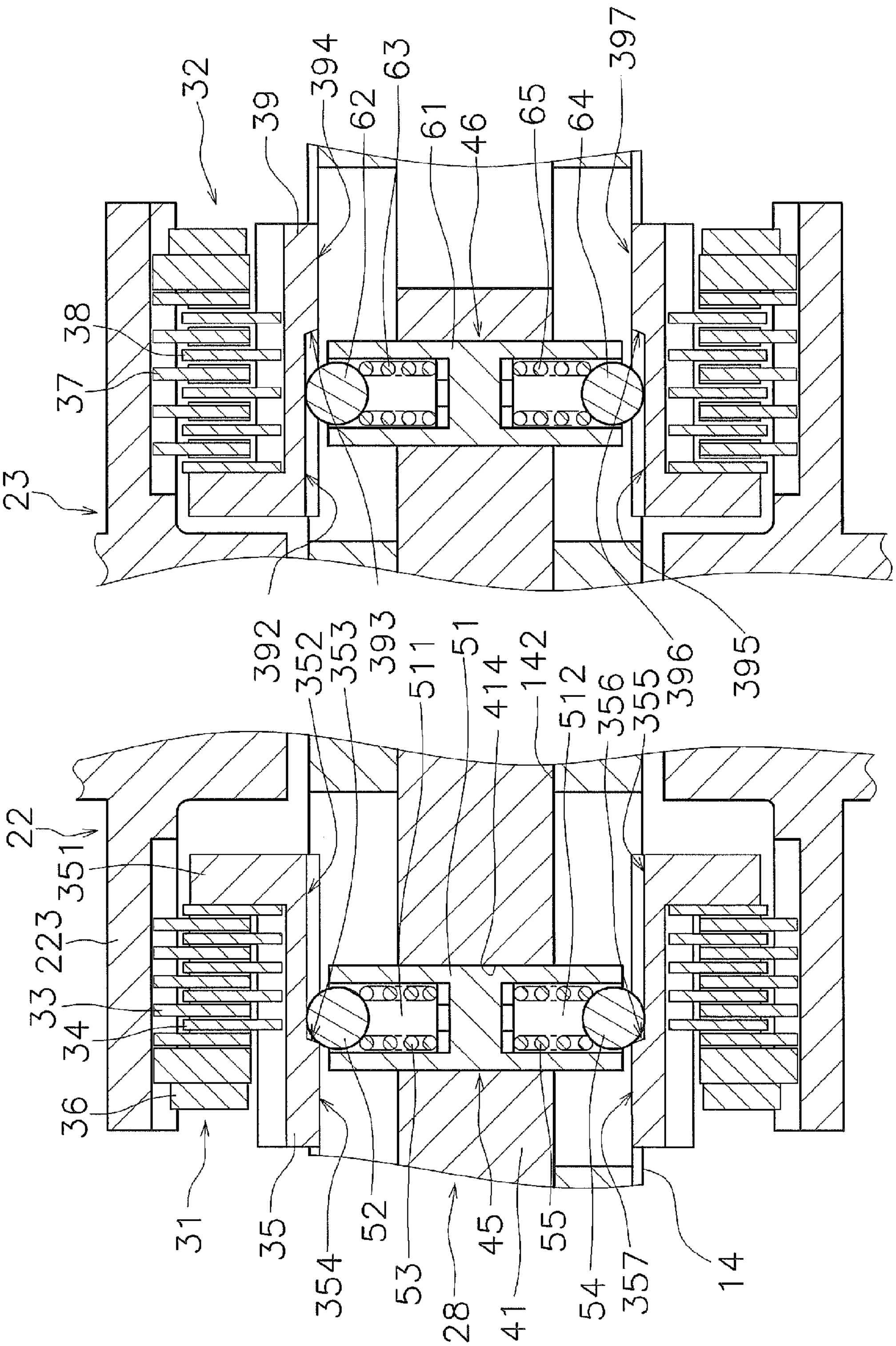
FIG. 5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356
355
396
395
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223
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354
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357
14

FIG. 6

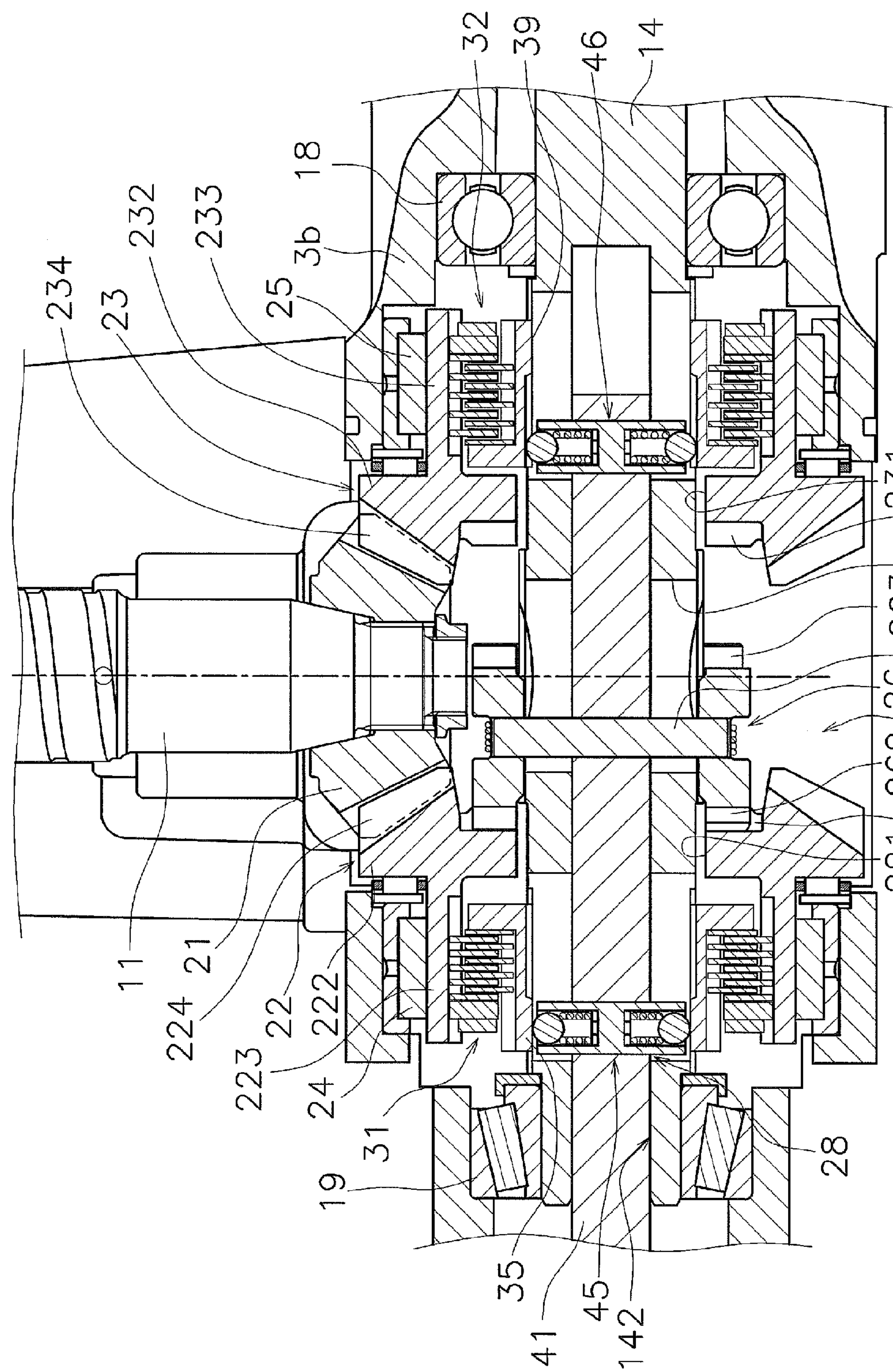
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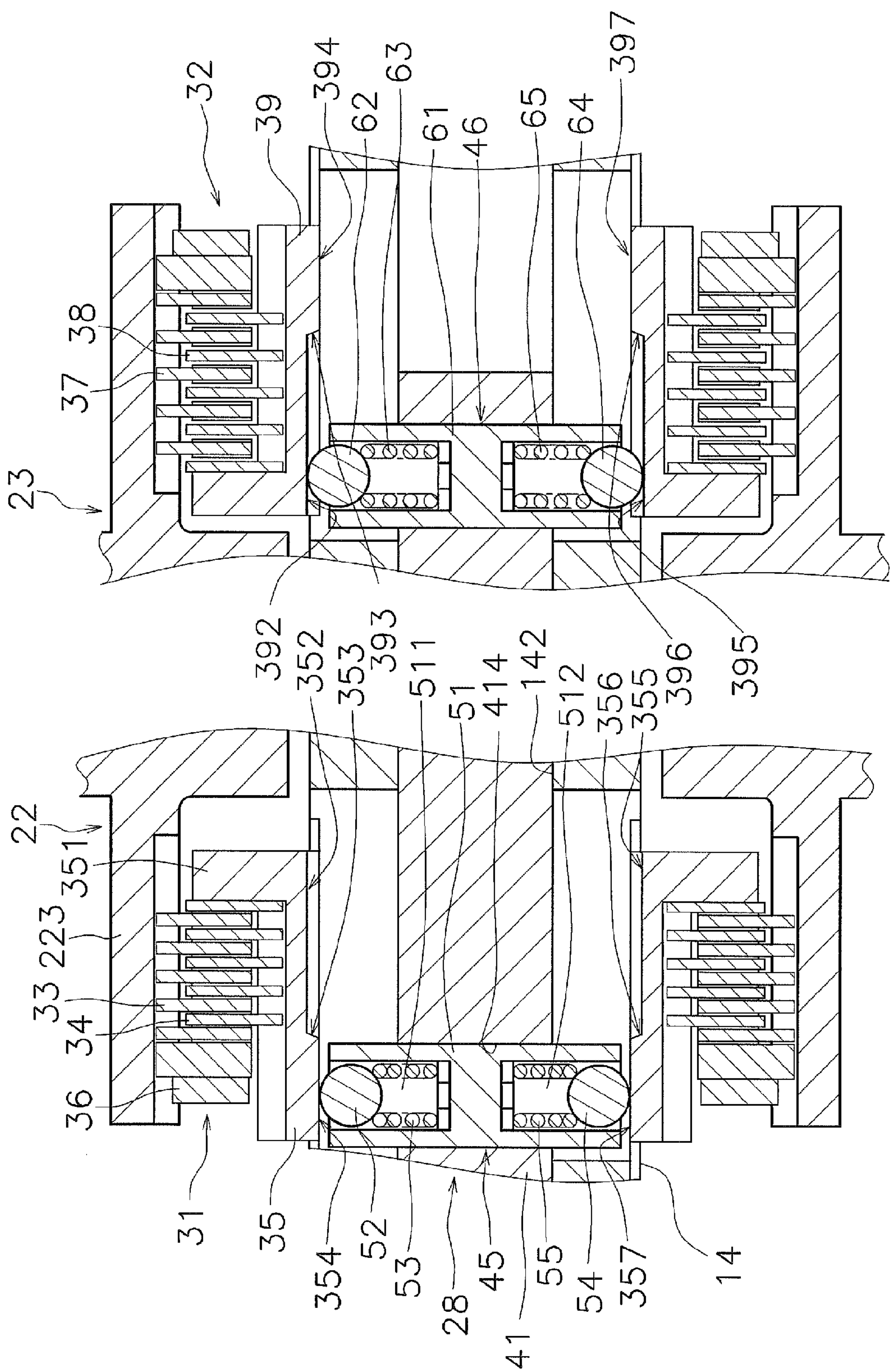
FIG. 7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414
142
512
356
355
22
351
223
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34
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31
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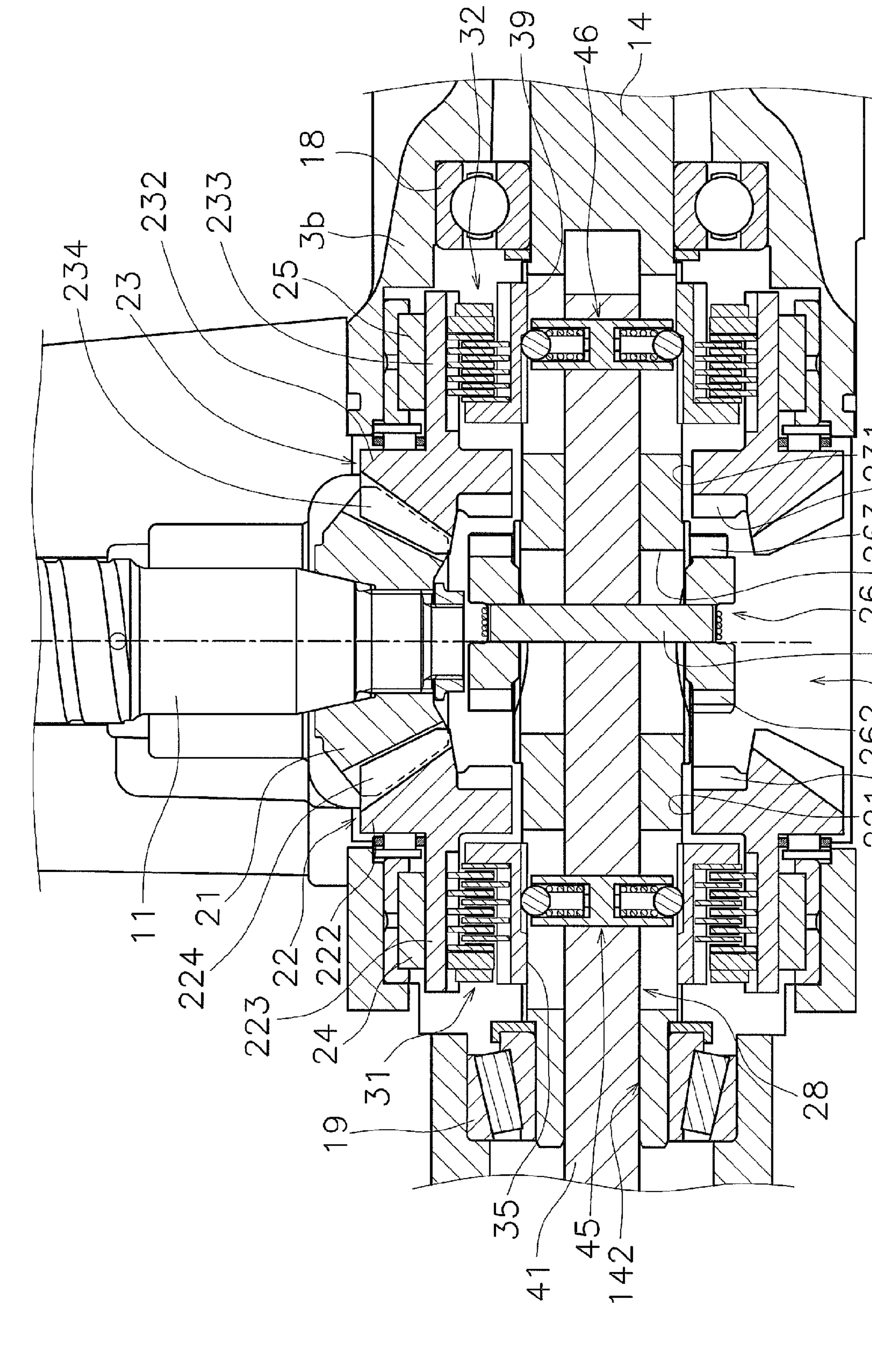
357
14

FIG. 8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141
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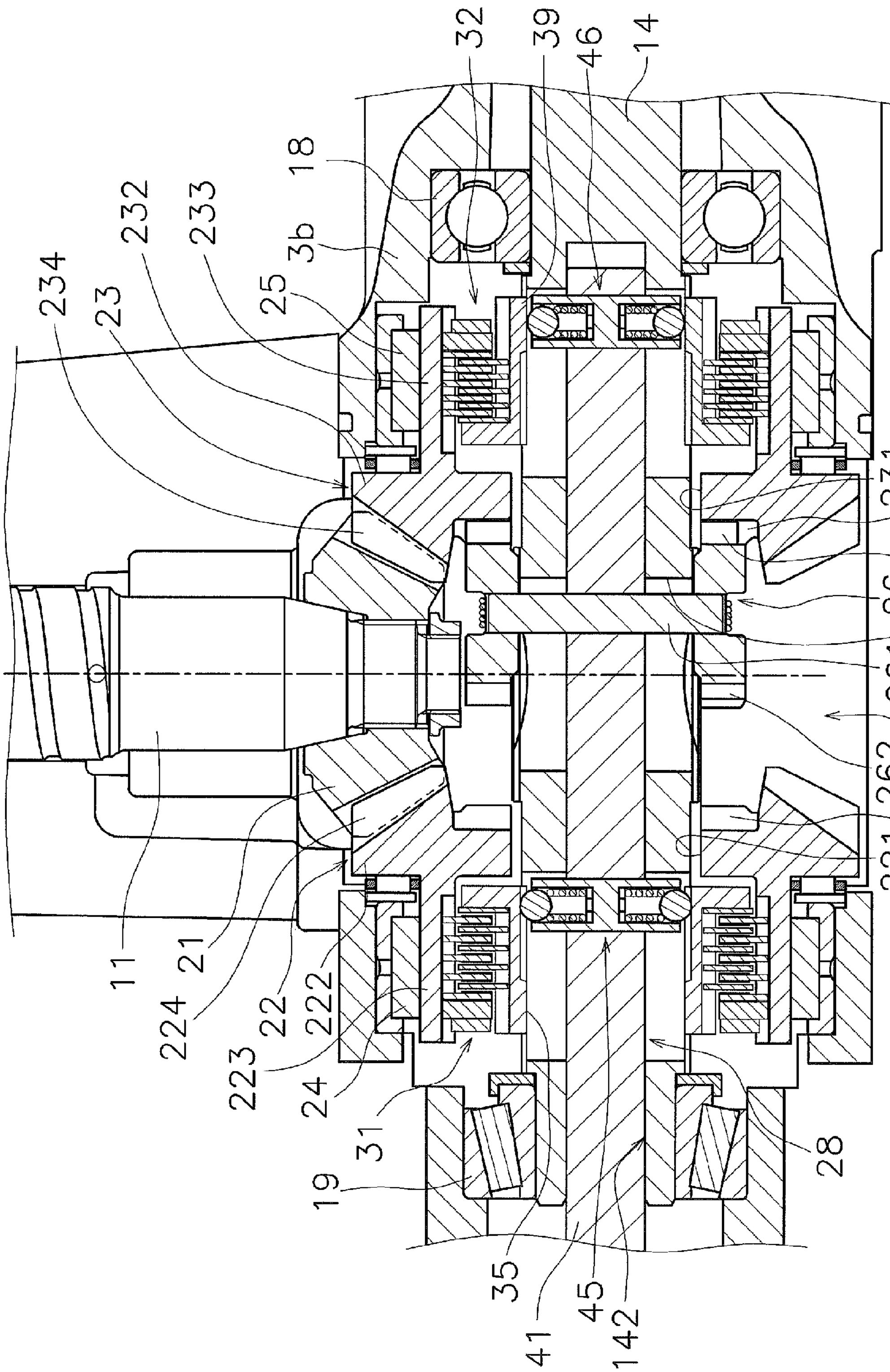
FIG. 9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142
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FIG. 10

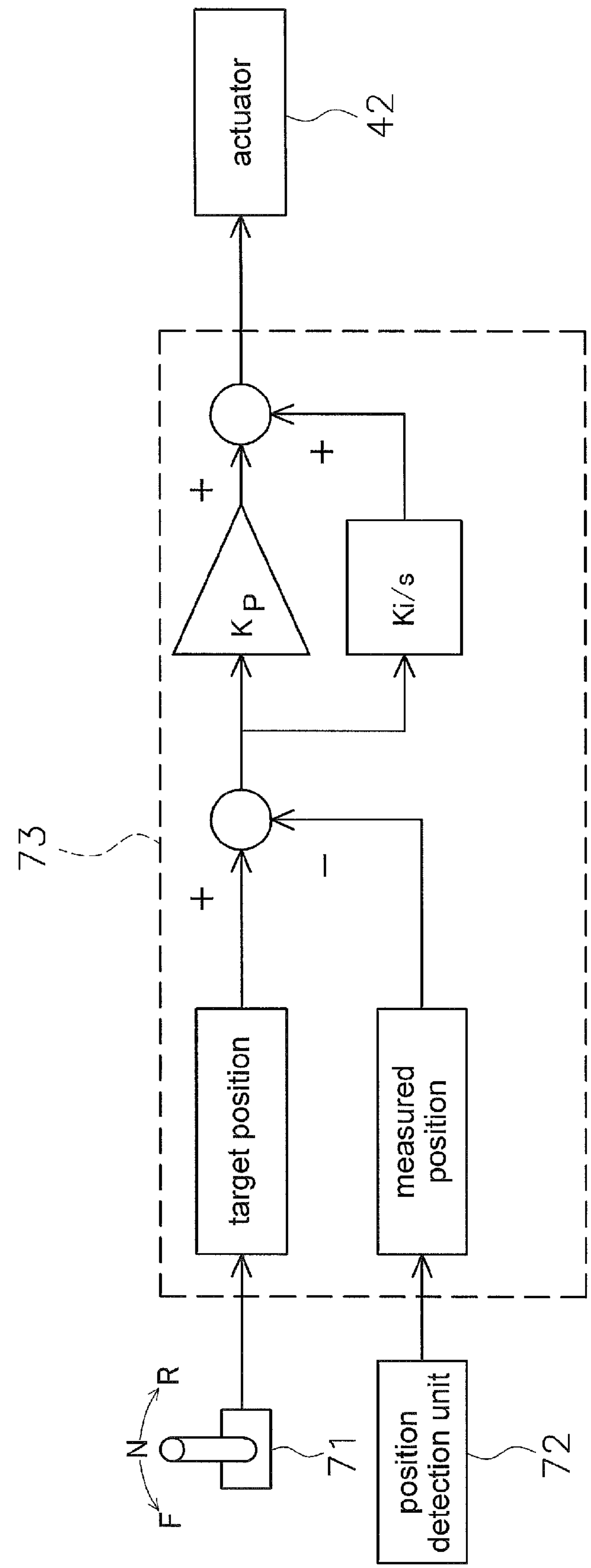
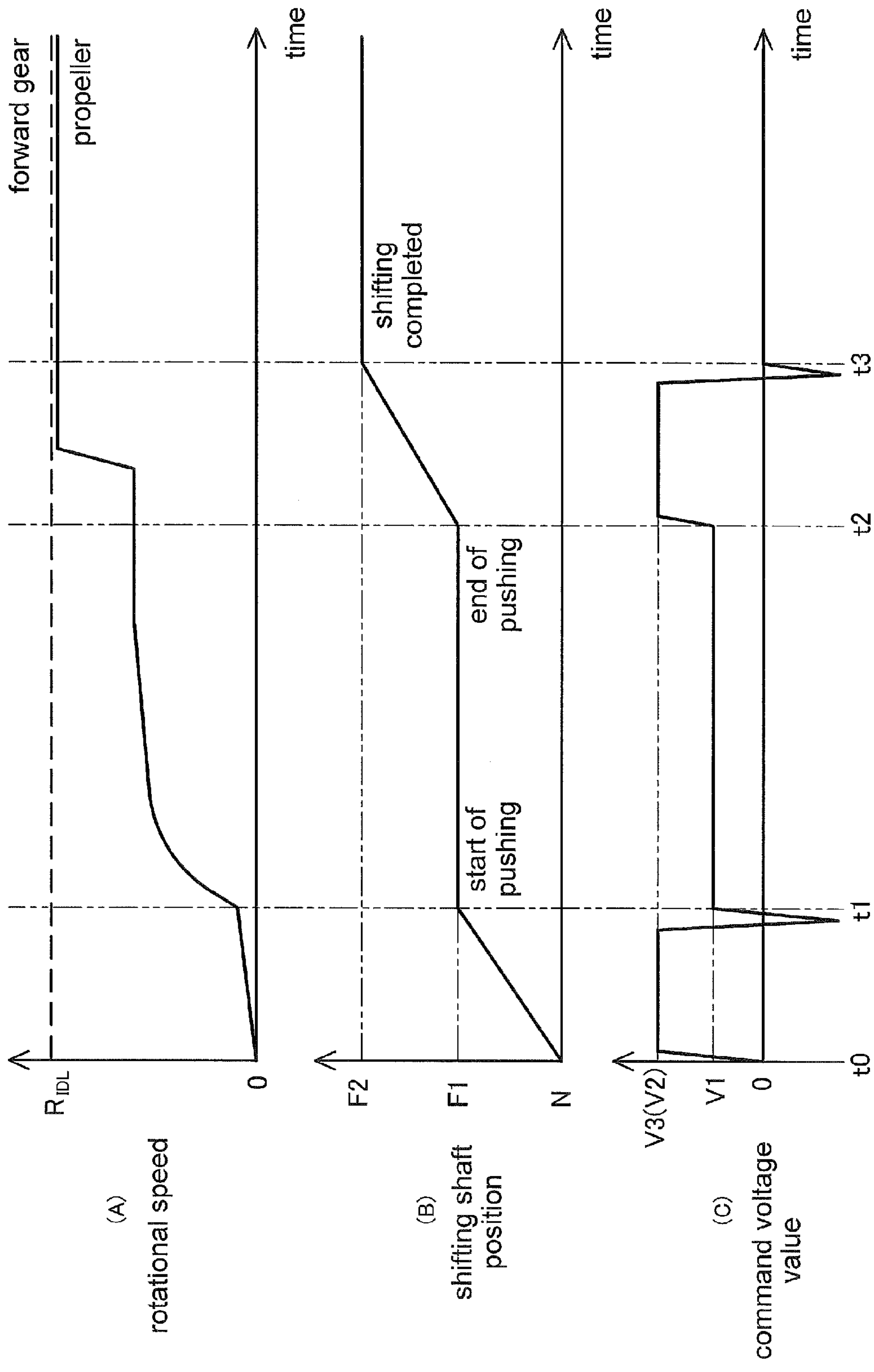

actuator
42
K_P
Ki/s
73
target position
measured position
F
N
R
71
position detection unit
72

FIG. 11



(A)
rotational speed
R_{IDL}
0
forward gear
propeller
time
(B)
shifting shaft position
F2
F1
N
start of pushing
end of pushing
shifting completed
time
(C)
command voltage value
V3(V2)
V1
0
time
t0
t1
t2
t3

FIG. 12

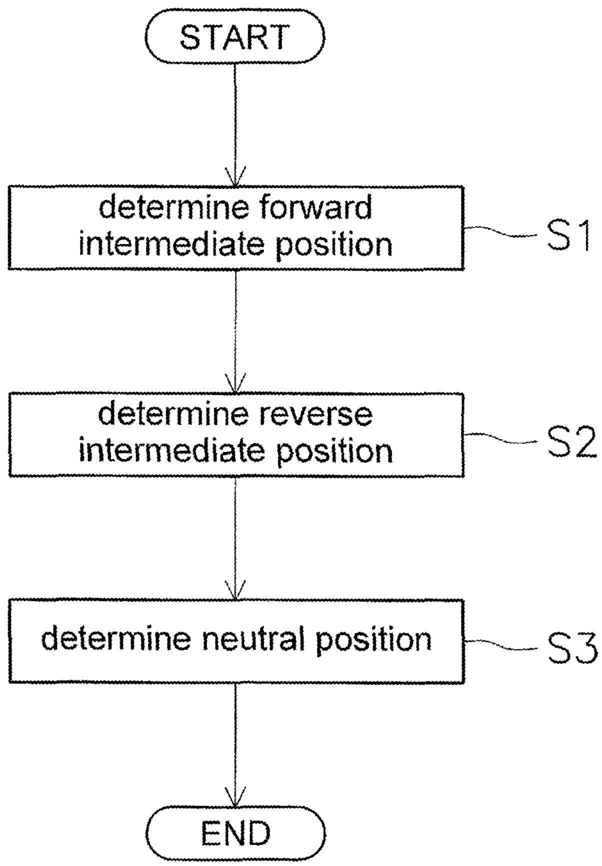

START
determine forward intermediate position
S1
determine reverse intermediate position
S2
determine neutral position
S3
END

FIG. 13

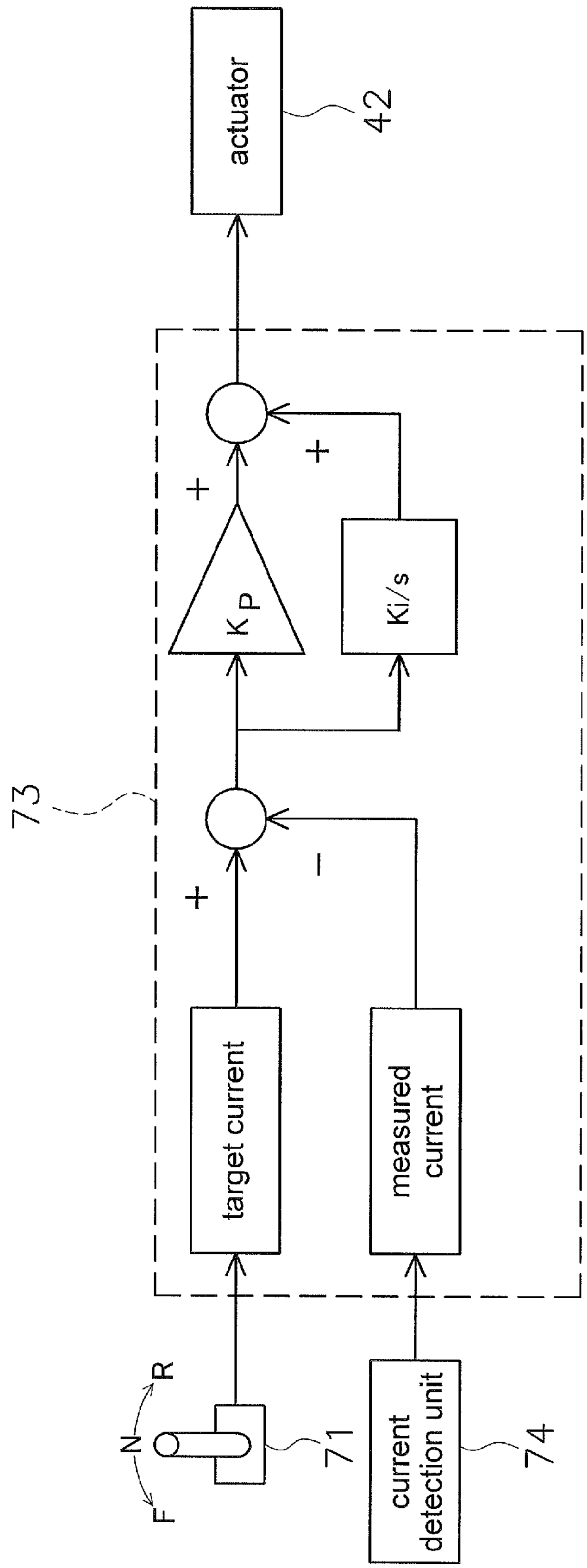

actuator
42
+
+
K_P
Ki/s
73
+
−
target current
measured current
F
N
R
71
current detection unit
74

FIG. 14

OUTBOARD MOTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an outboard motor.

2. Description of the Related Art

An outboard motor includes a shifting mechanism configured to change transmission of power from the engine to the propeller shaft to any one of forward, reverse, and neutral. Such a shifting mechanism includes a dog clutch, a forward gear, and a reverse gear. The shifting mechanism changes the direction in which power is transmitted to the propeller shaft by changing between connecting the dog clutch and the forward gear, and connecting the dog clutch and the reverse gear.

When the dog clutch and the forward gear become meshed together, a rotational speed difference may exist between the dog clutch and the forward gear. Due to this configuration, it is not easy to mesh the dog clutch and the forward gear together smoothly, and in some cases a shift shock is generated. In a similar manner, when the dog clutch and the reverse gear become meshed together, in some cases a shift shock is generated due to a rotational speed difference between the dog clutch and the reverse gear.

In order to suppress this type of shift shock, for example, the shifting mechanism of the outboard motor of Japanese Laid-Open Patent Publication 2009-190653 is equipped with a cone clutch. The cone clutch is disposed in line with the dog clutch along the direction of the axial line of the drive shaft, and is coupled to the dog clutch. Before the dog clutch and the forward gear mesh together, or the dog clutch and the reverse gear mesh together, the cone clutch frictionally engages against a contacting surface that is provided on the forward gear or on the reverse gear. In Japanese Laid-Open Patent Publication 2009-190653, it is explained that, due to this operation of the cone clutch, it is possible for the dog clutch and the forward gear, or the dog clutch and the reverse gear, to become meshed together in a state in which the rotation of the dog clutch and the rotation of the forward gear, or the rotation of the reverse gear, have been synchronized.

SUMMARY OF THE INVENTION

However, it is not easy to sufficiently synchronize the rotation of the dog clutch with the rotation of the forward gear, or with the rotation of the reverse gear, since the friction surface of the cone clutch that frictionally contacts against the contacting surface of the forward gear, or against the contacting surface of the reverse gear, is small. Due to this configuration, it is necessary for the steersman to adjust the frictional state of the cone clutch by appropriately operating the shift lever until the rotation of the dog clutch has become sufficiently synchronized with the rotation of the forward gear, or with the rotation of the reverse gear. However, this type of operation is complicated and is not desirable.

Moreover, in Japanese Laid-Open Patent Publication 2009-190653, it is disclosed that it is possible to mesh the dog clutch smoothly with the forward gear or with the reverse gear, provided that the synchronized rotational speed of the dog clutch is around 20% to 30% of the rotational speed of the forward gear, or the rotational speed of the reverse gear. However, in actual practice, in order to mesh the dog clutch smoothly with the forward gear or with the reverse gear, it is necessary to synchronize the rotational speed of the dog clutch better than above, and to make the rotational speed difference smaller than that disclosed in Japanese Laid-Open Patent Publication 2009-190653. Due to this, it is necessary to perform a more complicated operation of the type described above with the shift lever.

Preferred embodiments of the present invention provide an outboard motor that significantly reduces or prevents shift shock with a simple operation.

The outboard motor according to a preferred embodiment of the present invention includes an engine, a drive shaft, a drive gear, a propeller shaft, a forward gear, a reverse gear, a shift operating member, a dog clutch, a friction clutch, an actuator, and a control unit. The drive shaft extends downward from the engine. The drive gear is fixed to the drive shaft. The propeller shaft extends in a direction that intersects the drive shaft. The forward gear meshes with the drive gear. The reverse gear meshes with the drive gear. The shift operating member is configured to change between forward and reverse. The dog clutch is disposed on the propeller shaft. The dog clutch changes between connecting the forward gear to the propeller shaft and connecting the reverse gear to the propeller shaft by selectively meshing with the forward gear or the reverse gear according to operation of the shift operating member. The friction clutch includes a first friction surface that transmits rotation of the drive shaft and a second friction surface that transmits rotation of the propeller shaft. The friction clutch transmits rotation of the drive shaft to the propeller shaft by the first friction surface and the second friction surface contacting together. The actuator drives the friction clutch. The control unit is configured or programmed, before a shifting stage in which the dog clutch meshes with the forward gear or with the reverse gear, to execute synchronization control by controlling the actuator to contact the first friction surface and the second friction surface of the friction clutch together.

According to the various preferred embodiments of the present invention, it is possible to perform synchronization control at a high accuracy with the friction clutch by the control unit controlling the actuator. Due to this configuration, it is possible to significantly reduce or prevent shift shock with a simple operation.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of an outboard motor according to a preferred embodiment of the present invention.

FIG. **2** is a sectional view showing a shifting mechanism in a state in which a shift shaft is positioned at a neutral position.

FIG. **3** is an enlarged view of the shifting mechanism in the state in which the shift shaft is positioned at the neutral position.

FIG. **4** is an enlarged view of a link mechanism.

FIG. **5** is a sectional view showing the shifting mechanism in a state in which the shift shaft is positioned at a forward intermediate position.

FIG. **6** is an enlarged view of the shifting mechanism in the state in which the shift shaft is positioned at the forward intermediate position.

FIG. **7** is a sectional view showing the shifting mechanism in a state in which the shift shaft is positioned at a forward connection position.

FIG. **8** is an enlarged view of the shifting mechanism in the state in which the shift shaft is positioned at the forward connection position.

FIG. **9** is a sectional view showing the shifting mechanism in a state in which the shift shaft is positioned at a reverse intermediate position.

FIG. **10** is a sectional view showing the shifting mechanism in a state in which the shift shaft is positioned at a reverse connection position.

FIG. **11** is a block diagram of a control system of the outboard motor.

FIG. **12** is a timing chart showing synchronization control during forward shifting.

FIG. **13** is a flow chart showing a method for calibrating target positions for the shift shaft.

FIG. **14** is a block diagram showing a control system of an outboard motor according to a variant preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An outboard motor according to various preferred embodiments of the present invention will now be explained with reference to the drawings. FIG. **1** is a side view of the outboard motor **1** according to a preferred embodiment of the present invention. The outboard motor **1** includes an engine cover **2**, a casing **3**, a bracket **4**, and an engine **5**. The engine cover **2** houses the engine **5**. The casing **3** is disposed under the engine cover **2**. The outboard motor **1** is attached to the hull of a vessel via the bracket **4**.

The engine **5** is disposed within the engine cover **2**. The engine **5** includes a crankshaft **10**. The crankshaft **10** extends in the vertical direction. A drive shaft **11** is disposed within the casing **3**. The drive shaft **11** extends downward from the engine **5**, and extends in the vertical direction in the interior of the casing **3**. The drive shaft **11** is fixed to the crankshaft **10**.

The casing **3** includes an upper casing **3***a* and a lower casing **3***b*. The upper casing **3***a* is disposed below the engine cover **2**. The upper casing **3***a* is disposed between the engine cover **2** and the lower casing **3***b*. The lower casing **3***b* is disposed under the upper casing **3***a*.

A propeller **12** is disposed at the lower portion of the lower casing **3***b*. The propeller **12** is disposed underneath the engine **5**. The propeller **12** includes a propeller boss **13**. A propeller shaft **14** is disposed in the interior of the propeller boss **13**. The propeller shaft **14** extends in a direction that intersects the drive shaft **11**. In other words, the propeller shaft **14** extends along the front-back direction.

The outboard motor **1** includes a shifting mechanism **15**. The propeller shaft **14** is connected to the drive shaft **11** via the shifting mechanism **15**. The propeller shaft **14** transmits a drive force from the drive shaft **11** to the propeller **6**. The shifting mechanism **15** changes the rotational direction of the power that is transmitted from the drive shaft **11** to the propeller shaft **14**. The shifting mechanism **15** thus changes the direction of rotation of the propeller **6** between the direction to drive the hull to which the outboard motor **1** is mounted forward, and the direction to drive it in reverse.

FIG. **2** is a sectional view showing the structure within the lower casing **3***b*. As shown in FIG. **2**, the propeller shaft **14** is housed within the lower casing **3***b*. The propeller shaft **14** is rotatably supported by the lower casing **3***b* via bearings **18** and **19**.

The shifting mechanism **15** includes a drive gear **21**, a forward gear **22**, and a reverse gear **23**. The drive gear **21** is fixed to the lower end portion of the drive shaft **11**. The forward gear **22** and the reverse gear **23** are disposed in sequence along the front-back direction. In other words, the forward gear **22** and the reverse gear **23** are disposed in sequence along the direction of the axial line of the propeller shaft **14** (subsequently this will be termed the "propeller shaft axial direction"). The forward gear **22** and the reverse gear **23** are arranged to be coaxial with the propeller shaft **14**. The drive gear **21** is disposed between the forward gear **22** and the reverse gear **23**, and meshes with the forward gear **22** and with the reverse gear **23**.

The forward gear **22** includes a through hole **221**. The reverse gear **23** includes a through hole **231**. The propeller shaft **14** is inserted through the through hole **221** of the forward gear **22** and also through the through hole **231** of the reverse gear **23**. The forward gear **22** is provided on the propeller shaft **14** so as to be rotatable thereupon. Moreover, the forward gear **22** is provided on the propeller shaft **14** so as to shift along the propeller shaft axial direction. The reverse gear **23** is provided on the propeller shaft **14** so as to be rotatable thereupon. Moreover, the reverse gear **23** is provided on the propeller shaft **14** so as to shift along the propeller shaft axial direction.

The forward gear **22** includes a gear portion **222** and a tubular portion **223**. The gear portion **222** includes a toothed portion **222** and a dog portion **225**. The toothed portion **224** meshes with the drive gear **21** described above. The drive gear **21** and the toothed portion **224** are preferably both bevel gears. The dog portion **225** is positioned radially inward from the toothed portion **224**. The dog portion **225** meshes with a dog clutch **26** that will be described hereinafter. The tubular portion **223** projects from the gear portion **222** along the propeller shaft axial direction. The tubular portion **223** is rotatably supported by the lower casing **3***b* via a bearing **24**.

Similarly, the reverse gear **23** includes a gear portion **232** and a tubular portion **233**. The gear portion **232** includes a toothed portion **234** and a dog portion **235**. The toothed portion **234** meshes with the drive gear **21** described above. The toothed portion **234** is preferably a bevel gear. The dog portion **235** is positioned radially inward from the toothed portion **234**. The dog portion **235** meshes with the dog clutch **26** described hereinafter. The tubular portion **233** is rotatably supported by the lower casing **3***b* via a bearing **25**. The tubular portion **233** projects from the gear portion **232** along the propeller shaft axial direction.

The shifting mechanism **15** includes the dog clutch **26**, friction clutches **31** and **32**, and a connection changeover mechanism **28**. The dog clutch **26** is configured to change between connecting the propeller shaft **14** to the forward gear **22**, and connecting the propeller shaft **14** to the reverse gear **23**. The dog clutch **26** is disposed on the propeller shaft **14**. The dog clutch **26** is disposed between the forward gear **22** and the reverse gear **23**. The dog clutch **26** is fitted on the propeller shaft **14** so that it cannot rotate thereupon. Accordingly, the dog clutch **26** rotates together with the propeller shaft **14**. Moreover, the dog clutch **26** is mounted on the propeller shaft **14** so as to shift along the propeller shaft axial direction.

The dog clutch **26** includes a shaft portion **261**, a forward dog portion **262**, and a reverse dog portion **263**. The propeller shaft **14** includes a hole **141** that pierces through the propeller shaft **14** in the diametrical direction. The hole **141** is a slot that extends along the propeller shaft axial direction. The shaft portion **261** of the dog clutch **261** is inserted through the hole **141** in the propeller shaft **14**. Along the propeller shaft axial direction, the forward dog portion **262** faces the dog portion **225** of the forward gear **22**. Similarly, along the propeller shaft axial direction, the reverse dog portion **263** faces the dog portion **235** of the reverse gear **23**.

The friction clutches **31** and **32** transmit the rotation of the drive shaft **11** to the propeller shaft **14** by frictional force. The friction clutches **31** and **32** include a forward clutch **31** and a reverse clutch **32**. The forward clutch **31** and the reverse clutch **32** are disposed in sequence along the propeller shaft axial direction with the dog clutch **26**. The forward clutch **31** transmits the rotation of the forward gear **22** to the propeller shaft **14** by frictional force. The forward clutch **31** is disposed between the forward gear **22** and the propeller shaft **14**. The reverse clutch **32** transmits the rotation of the reverse gear **23** to the propeller shaft **14** by frictional force. The reverse clutch **32** is disposed between the reverse gear **23** and the propeller shaft **14**.

FIG. **3** is an enlarged view of the shifting mechanism **15**. As shown in FIG. **3**, the forward clutch **31** includes a plurality of first clutch plates **33** and **34** and a first clutch piston **35**. The plurality of first clutch plates **33** and **34** include a plurality of outer first clutch plates **33** and a plurality of inner first clutch plates **34**. It should be understood that, in FIG. **3**, a reference symbol **33** is appended to only one of the outer first clutch plates **33**, while reference symbols for the other outer first clutch plates **33** are omitted. Similarly, a reference symbol **34** is appended to only one of the inner first clutch plates **34**, while reference symbols for the other inner first clutch plates **34** are omitted. The outer first clutch plates **33** and the inner first clutch plates **34** are arranged alternatingly along the propeller shaft axial direction.

The first clutch piston **35** includes a tubular shaped portion. The first clutch piston **35** is mounted on the propeller shaft **14** so as to shift along the propeller shaft axial direction. The first clutch piston **35** is mounted on the propeller shaft **14** so as not to be rotatable with respect to the propeller shaft **14**. Accordingly, the first clutch piston **35** rotates together with the propeller shaft **14**. For example, the first clutch piston **35** may be splined to the outer circumferential surface of the propeller shaft **14**.

The outer first clutch plates **33** are fitted to the inner circumferential surface of the tubular portion **223** of the forward gear **22**. The outer first clutch plates **33** are mounted in the tubular portion **223** of the forward gear **22** so as to shift along the propeller shaft axial direction. A retainer member **36** is attached to the tubular portion **223** of the forward gear **22**. The retainer member **36** is configured so that the outer first clutch plates **33** cannot detach from the tubular portion **223** of the forward gear **22**. The outer first clutch plates **33** are mounted in the tubular portion **223** of the forward gear **22** so as not to be rotatable with respect thereto. For example, the outer first clutch plates **33** may be splined to the inner circumferential surface of the tubular portion **223** of the forward gear **22**. Accordingly, the outer first clutch plates **33** rotate together with the tubular portion **223** of the forward gear **22**.

The inner first clutch plates **34** are fitted to the outer circumferential surface of the first clutch piston **35**. The inner first clutch plates **34** are mounted to the first clutch piston **35** so as to shift along the propeller shaft axial direction with respect thereto. Moreover, the inner first clutch plates **34** are mounted to the first clutch piston **35** so as not to be rotatable with respect thereto. Accordingly, the inner first clutch plates **34** rotate together with the first clutch piston **35**. For example, the inner first clutch plates **34** may be splined to the outer circumferential surface of the first clutch piston **35**. The inner first clutch plates **34** rotate together with the first clutch piston **35** and the propeller shaft **14**.

The first clutch piston **35** includes a flange portion **351**. The flange portion **351** opposes the plurality of first clutch plates **33** and **34** along the propeller shaft axial direction. The flange portion **351** presses the inner first clutch plates **34** toward the outer first clutch plates **33** due to the first clutch piston **35** shifting along the propeller shaft axial direction. Due to this configuration, the outer first clutch plates **33** and the inner first clutch plates **34** are contacted together, and the forward clutch **31** is put into a connected state. Accordingly, the surfaces of the outer first clutch plates **33** correspond to first friction surfaces that transmit the rotation of the drive shaft **11**. Moreover, the surfaces of the inner first clutch plates **34** correspond to second friction surfaces that transmit the rotation of the drive shaft **11**. It should be understood that, in the state in which the flange portion **351** does not press upon the inner first clutch plates **34**, due to the action of lubricating oil or the like, the inner first clutch plates **34** and the outer first clutch plates **33** operate so as to be mutually disengaged.

The reverse clutch **32** includes a structure similar to that of the forward clutch **31**. The reverse clutch **32** includes a plurality of second clutch plates **37** and **38** and a second clutch piston **39** that presses upon the second clutch plates **37** and **38**. The plurality of second clutch plates **37** and **38** include a plurality of outer second clutch plates **37** and a plurality of inner second clutch plates **38**. It should be understood that, in FIG. **3**, a reference symbol **37** is appended to only one of the outer second clutch plates **37**, while reference symbols for the other outer second clutch plates **37** are omitted. Similarly, a reference symbol **38** is appended to only one of the inner second clutch plates **38**, while reference symbols for the other inner second clutch plates **38** are omitted.

The outer second clutch plates **37** have a structure similar to that of the outer first clutch plates **33** described above. The inner second clutch plates **38** have a structure similar to that of the inner first clutch plates **34** described above. Moreover, the second clutch piston **39** includes a structure similar to that of the first clutch piston **35** described above. Accordingly, detailed explanation of the reverse clutch **32** will be omitted.

The connection changeover mechanism **28** changes the connections of the dog clutch **26** and the connections of the friction clutches **31** and **32**. The connection changeover mechanism **28** includes a shift shaft **41**. The shift shaft **41** is disposed within the lower casing **3***b*. The shift shaft **41** is disposed so as to extend along the propeller shaft axial direction. In more detail, the propeller shaft **14** includes a hole **142** that extends along the propeller shaft axial direction. The shift shaft **41** is disposed in the hole **142** of the propeller shaft **14**. As shown in FIG. **2**, one end of the shift shaft **41** projects out from the hole **142** of the propeller shaft **14** along the propeller shaft axial direction. The shift shaft **41** is configured to shift along the propeller shaft axial direction. The connection changeover mechanism **28** changes the connection between the dog clutch **26** and the forward gear **22**, the connection of the forward clutch **31**, the connection between the dog clutch **26** and the reverse gear **23**, and the connection of the reverse clutch **32** according to the position of the shift shaft **41**.

As shown in FIG. **1**, the shifting mechanism **15** includes an actuator **42**, a transmission shaft **43**, and a link mechanism **44**. The actuator **42** shifts the shift shaft **41** along the propeller shaft axial direction via the transmission shaft **43** and the link mechanism **44**. For example, the actuator **42** may be an electrically operated cylinder. The actuator **42** is attached to the lower casing **3***b*. The output shaft of the actuator **42** is connected to the transmission shaft **43**. The actuator **42** shifts the transmission shaft **43** along the axial direction of the transmission shaft **43**. In other words, the actuator **42** shifts the transmission shaft **43** in the vertical direction.

The transmission shaft **43** is disposed within the lower casing **3***b* so as to extend in the vertical direction. The transmission shaft **43** transmits the operation of the actuator **42** to the shift shaft **41**. The link mechanism **44** converts and transmits the movement of the transmission shaft **43** in the vertical direction into movement of the shift shaft **41** along the propeller shaft axial direction.

FIG. **4** is an enlarged view of the link mechanism **44**. As seen from the side, the link mechanism **44** preferably has a bent shape. The link mechanism **44** includes a rotation support portion **441**. The rotation support portion **441** is connected to the bent portion of the link mechanism **44**. The rotation support portion **441** is rotatably supported by the lower casing **3***b*. The link mechanism **44** is provided so as to rotate about the rotation support portion **441** as a center. The link mechanism **44** includes a first end portion **442** and a second end portion **443**. The first end portion **442** is rotatably connected to the transmission shaft **43**. The first end portion **442** is connected to the transmission shaft **43** via a first pin member **444**. The second end portion **443** is rotatably connected to the shift shaft **41**. In detail, the second end portion **443** is connected to the shift shaft **41** via a second pin member **445**.

In more detail, the end portion of the shift shaft **41** includes a first flange portion **411**, a second flange portion **412**, and an engaging groove portion **413**. The first flange portion **411**, the engaging groove portion **413**, and the second flange portion **412** are arranged in that sequence along the axial direction of the shift shaft **41**. The engaging groove portion **413** is positioned between the first flange portion **411** and the second flange portion **412**. The second pin member **445** is disposed within the engaging groove portion **413**.

When the transmission shaft **43** shifts upward, the link mechanism **44** rotates in the clockwise direction in FIG. **4** about the rotation support portion **441** as a center. Due to this configuration, the first flange portion **411** is pushed by the second pin member **445**, and the shift shaft **41** is shifted leftward in FIG. **4** (hereinafter this will be termed the "forward shifting direction"). Conversely, when the transmission shaft **43** shifts downward, the link mechanism **44** rotates in the counterclockwise direction in FIG. **4** about the rotation support portion **441** as a center. Due to this configuration, the second flange portion **412** is pushed by the second pin member **445**, and the shift shaft **41** is shifted rightward in FIG. **4** (hereinafter this will be termed the "reverse shifting direction").

The shift shaft **41** transmits the operation of the actuator **42** to the dog clutch **26**, the forward clutch **31**, and the reverse clutch **32**. As shown in FIG. **2**, the shift shaft **41** is linked to the shaft portion **261** of the dog clutch **26**. The dog clutch **26** is shifted along the propeller shaft axial direction by the shift shaft **41** shifting along the propeller shaft axial direction. Due to this configuration, the connection/disconnection of the dog clutch **26** is changed. Moreover, the connection/disconnection of the forward clutch **31** is changed by the shift shaft **41** shifting along the propeller shaft axial direction. Yet further, the connection/disconnection of the reverse clutch **32** is changed by the shift shaft **41** shifting along the propeller shaft axial direction.

In detail, the connection changeover mechanism **28** includes a first detent mechanism **45** and a second detent mechanism **46**. The first detent mechanism **45** and the second detent mechanism **46** are both attached to the shift shaft **41**. The first detent mechanism **45** is disposed within the first clutch piston **35**. As shown in FIG. **3**, the first detent mechanism **45** includes a detent main body portion **51**, a first engagement member **52**, a first elastic member **53**, a second engagement member **54**, and a second elastic member **55**.

The detent main body portion **51** preferably has a tubular shape. The detent main body portion **51** is arranged so that the axial line of the detent main body portion **51** is orthogonal or substantially orthogonal to the direction of the axial line of the shift shaft **41**. The shift shaft **41** includes a hole **414** that pierces through the shift shaft **41** in the direction orthogonal or substantially orthogonal to the direction of the axial line of the shift shaft **41**. The detent main body portion **51** is inserted into the hole **414** of the shift shaft **41**. Both ends of the detent main body portion **51** project from the outer circumferential surface of the shift shaft **41** in diametrically opposite radial directions. The detent main body portion **51** includes a first reception portion **511** and a second reception portion **512**. The first reception portion **511** is a hole that extends along the direction of the axial line of the detent main body portion **51**. The first reception portion **511** opens at one end of the detent main body portion **51**. The second reception portion **512** is a hole that extends along the direction of the axial line of the detent main body portion **51**. The second reception portion **512** opens at the other end of the detent main body portion **51**.

The first elastic member **53** is disposed within the first reception portion **511**. The first elastic member **53** pushes the first engagement member **52** towards the inner circumferential surface of the first clutch piston **35**. The second elastic member **55** is disposed within the second reception portion **512**. The second elastic member pushes the second engagement member **54** towards the inner circumferential surface of the second clutch piston **35** on the other side thereof. The first elastic member **53** and the second elastic member **55** may, for example, be compression coil springs. However, the first elastic member **53** and the second elastic member **55** are not limited to being compression coil springs; they may be components of any type that generate elastic forces to push the first engagement member **52** and second engagement member **54** appropriately.

The first engagement member **52** and the second engagement member **54** are preferably spherical members. A portion of the first engagement member **52** is disposed within the first reception portion **511**. Another portion of the first engagement member **52** projects from the detent main body portion **51**, and contacts against the inner circumferential surface of the first clutch piston **35**. Similarly, a portion of the second engagement member **54** is disposed within the second reception portion **512**. Another portion of the second engagement member **54** projects from the detent main body portion **51**, and contacts against the inner circumferential surface of the first clutch piston **35** on the other side thereof.

The inner circumferential surface of the first clutch piston **35** includes a first flat surface **352**, a first step portion **353**, and a second flat surface **354**. The first flat surface **352** is positioned further outward in the radial direction of the first clutch piston **35** than the second flat surface **354**. The first step portion **353** is positioned between the first flat surface **352** and the second flat surface **354**.

On its other side, the inner circumferential surface of the first clutch piston **35** includes a third flat surface **355**, a second step portion **356**, and a fourth flat surface **357**. The third flat surface **355** is positioned further outward in the radial direction of the first clutch piston **35** than the fourth flat surface **357**. The second step portion **356** is positioned between the third flat surface **355** and the fourth flat surface **357**.

In the first detent mechanism **45**, when the shift shaft **41** shifts in the forward shifting direction, the first engagement member **52** is engaged to the first step portion **353**, and the second engagement member **54** is engaged to the second step portion **356**. Due to this configuration, the first detent mechanism **45** shifts the first clutch piston **35** in the forward shifting direction.

The second detent mechanism **46** is disposed within the second clutch piston **39**. The second detent mechanism **46** includes a detent main body portion **61**, a first engagement member **62**, a first elastic member **63**, a second engagement member **64**, and a second elastic member **65**. The detent main body portion **61**, the first engagement member **62**, the first elastic member **63**, the second engagement member **64**, and the second elastic member **65** of the second detent mechanism **46** preferably are respectively identical to the detent main body portion **51**, the first engagement member **52**, the first elastic member **53**, the second engagement member **54**, and the second elastic member **55** of the first detent mechanism **45**.

The inner circumferential surface of the second clutch piston **39** includes a first flat surface **392**, a first step portion **393**, and a second flat surface **394**. The first flat surface **392**, the first step portion **393**, and the second flat surface **394** of the second clutch piston **39** preferably are respectively identical to the first flat surface **352**, the first step portion **353**, and the second flat surface **354** of the first clutch piston **35**. On its other side, the inner circumferential surface of the second clutch piston **39** includes a third flat surface **395**, a second step portion **396**, and a fourth flat surface **397**. The third flat surface **395**, the second step portion **396**, and the fourth flat surface **397** of the second clutch piston **39** preferably are respectively identical to the third flat surface **355**, the second step portion **356**, and the fourth flat surface **357** of the first clutch piston **35**.

In the second detent mechanism **46**, when the shift shaft **41** shifts in the reverse shifting direction, the first engagement member **62** is engaged to the first step portion **393**, and the second engagement member **64** is engaged to the second step portion **396**. Due to this configuration, the second detent mechanism **46** shifts the second clutch piston **39** in the reverse shifting direction.

Next, the operation for shifting the dog clutch **26** and the friction clutches **31** and **32** by the shifting mechanism **15** will be explained. FIG. **2** described above shows the shifting mechanism **15** in a state in which the shift shaft **41** is positioned in its neutral position (hereinafter this will be termed the "neutral state"). By the shift shaft **41** shifting from its neutral position in the forward shifting direction, it shifts from its neutral position through a forward intermediate position to a forward connection position.

FIG. **5** shows the shifting mechanism **15** in a state in which the shift shaft **41** is positioned at the forward intermediate position (hereinafter this will be termed the "forward synchronizing state"). FIG. **6** is an enlarged view of the shifting mechanism **15** in the forward synchronizing state. Moreover, FIG. **7** shows the shifting mechanism **15** in a state in which the shift shaft **41** is positioned at the forward connection position (hereinafter this will be termed the "forward connected state"). Yet further, FIG. **8** is an enlarged view of the shifting mechanism **15** in the forward connected state. The forward intermediate position shown in FIG. **5** is a position between the neutral position shown in FIG. **2** and the forward connection position shown in FIG. **7**.

As shown in FIG. **2**, in the neutral state, the shaft portion **261** of the dog clutch **26** is positioned directly under the axial line of the drive shaft **11**. The forward dog portion **262** of the dog clutch **26** is separated from the dog portion **225** of the forward gear **22**. Moreover, the reverse dog portion **263** of the dog clutch **26** is separated from the dog portion **235** of the reverse gear **23**. Accordingly, the dog clutch **26** is disconnected both from the forward gear **22** and from the reverse gear **23**.

Furthermore, as shown in FIG. **3**, in the neutral state, the first detent mechanism **45** releases engagement with the first clutch piston **35**. In other words, the first engagement member **52** does not press against the first step portion **353**, and also the second engagement member **54** does not press against the second step portion **356**. Due to this configuration, the inner second clutch plates **34** and the outer second clutch plates **33** of the forward clutch **31** are disconnected from one another. Due to this configuration, the forward clutch **31** is in the disconnected state. It should be understood that it would be acceptable, in the neutral state, for the first engagement member **52** of the first detent mechanism **45** to contact against the first step portion **353**. Moreover, it would also be acceptable, in the neutral state, for the second engagement member **54** of the first detent mechanism **45** to contact against the second step portion **356**.

In a similar manner to the case with the first detent mechanism **45**, in the neutral state, the second detent mechanism **46** releases engagement with the second clutch piston **39**. In other words, the first engagement member **62** of the second detent mechanism **46** does not press against the first step portion **393**. Moreover, the second engagement member **64** of the second detent mechanism **46** does not press against the second step portion **396**. Due to this configuration, the reverse clutch **32** is in the disconnected state.

It should be understood that, in the neutral state, the first engagement member **52** of the first detent mechanism **45** contacts against the first flat surface **352**, and also the second engagement member **54** contacts against the third flat surface **355**. Moreover, in the neutral state, the first engagement member **62** of the second detent mechanism **46** contacts against the first flat surface **392**, and also the second engagement member **64** contacts against the third flat surface **395**.

As described above, in the neutral state, the connection changeover mechanism **28** puts the dog clutch **26** and the forward gear **22** into the disconnected state, and also puts the forward clutch **31** into the disconnected state. Moreover, in the neutral state, the connection changeover mechanism **28** puts the dog clutch **26** and the reverse gear **23** into the disconnected state, and also puts the reverse clutch **32** into the disconnected state. Accordingly, in the neutral state, the rotation of the drive shaft **11** is not transmitted to the propeller shaft **14**.

When the shift shaft **41** shifts from the neutral position in the forward shifting direction, the first engagement member **52** of the first detent mechanism **45** pushes the first step portion **353** in the forward shifting direction, and the second engagement member **54** pushes the second step portion **356** in the forward shifting direction. Due to this configuration, the first clutch piston **35** shifts in the forward shifting direction, and presses upon the inner first clutch plates **34** and the outer first clutch plates **33** of the forward clutch **31**. As a result, contact between the inner first clutch plates **34** and the outer first clutch plates **33** of the forward clutch **31** is started, and the shifting mechanism **15** transitions into the forward synchronizing state shown in FIG. **5**.

In the forward synchronizing state, the shaft portion **261** of the dog clutch **26** is shifted in the forward shifting direction from the position directly under the axial line of the drive shaft **11**. However, the forward dog portion **262** of the dog clutch **26** is still separated from the dog portion **225** of the forward gear **22**. Moreover, the reverse dog portion **263** of the dog clutch **26** is separated from the dog portion **235** of the reverse gear **22**. Accordingly, the dog clutch **26** is disconnected both from the forward gear **22** and from the reverse gear **23**.

Moreover, as shown in FIG. **6**, in the forward synchronizing state, the first detent mechanism **45** is engaged to the first clutch piston **35**. In other words, the first engagement member **52** is contacted against the first step portion **353**, and the second engagement member **54** is contacted against the second step portion **356**. The first engagement member **52** presses against the first step portion **353** and the second engagement member **54** presses against the second step portion **356**, so as to make the inner first clutch plates **34** and the outer first clutch plates **33** of the forward clutch **31** contact one another. Due to this configuration, the forward clutch **31** is put into the connected state. It should be understood that, the more the shift shaft **41** is shifted in the forward shifting direction, the stronger the pressure becomes with which the inner first clutch plates **34** and the outer first clutch plates **33** of the forward clutch **31** are squeezed together.

Furthermore, in the forward synchronizing state, engagement of the second detent mechanism **46** to the second clutch piston **39** is released. In other words, the first engagement member **62** of the second detent mechanism **46** is separated from the first step portion **393**, and the second engagement member **64** is separated from the second step portion **396**. Accordingly, the first engagement member **62** does not push against the first step portion **393**, and the second engagement member **64** does not push against the second step portion **396**. Due to this configuration, the reverse clutch **32** remains in the disconnected state.

Thus, as described above, in the forward synchronizing state, the connection changeover mechanism **28**, along with leaving the dog clutch **26** and the forward gear **22** in the disconnected state, also puts the forward clutch **31** into the connected state. Moreover, in the forward synchronizing state, the connection changeover mechanism **28**, along with leaving the dog clutch **26** and the reverse gear **23** in the disconnected state, also leaves the reverse clutch in the disconnected state. Accordingly, in the forward synchronizing state, the rotation of the drive shaft **11** is transmitted to the propeller shaft **14** via the forward clutch **31**. In the forward synchronizing state, the inner first clutch plates **34** and the outer first clutch plates **33** of the forward clutch **31** transmit the rotation of the drive shaft **11** to the propeller shaft **14** while mutually slipping past one another to a certain extent. Due to this configuration, the forward gear **22** and the dog clutch **26** are mutually synchronized by the dog clutch **26** rotating along with the propeller shaft **14**.

When the shift shaft **41** is driven further in the forward shifting direction from its forward intermediate position, and the force exerted by the first detent mechanism **45** upon the first clutch piston **35** becomes greater than a predetermined value, the first engagement member **52** shifts radially inward of the shift shaft **41** against the resistance of the elastic force of the first elastic member **53** which is overcome. Moreover, the second engagement member **54** shifts radially inward of the shift shaft **41** against the resistance of the elastic force of the second elastic member **55** which is overcome. Due to this configuration, the first engagement member **52** shifts in the forward shifting direction by riding over the first step portion **353**. Moreover, the second engagement member **54** shifts in the forward shifting direction by riding over the second step portion **356**. Due to this configuration, the engagement of the first detent mechanism **45** to the first clutch piston **35** is released. As a result, the shift shaft **41** shifts from the forward intermediate position to the forward connection position, and the shifting mechanism **15** transitions into the forward connected state shown in FIG. **7**.

In the forward connected state, the shaft portion **261** of the dog clutch **26** shifts further in the forward direction from its position directly below the axial line of the drive shaft. The dog portion **262** of the dog clutch **26** is also meshed with the dog portion **225** of the forward gear **22**. Moreover, the reverse dog portion **263** of the dog clutch **26** is disengaged from the dog portion **235** of the reverse gear **23**. Accordingly, the dog clutch **26** is connected to the forward gear **22**, and is disconnected from the reverse gear **23**.

Moreover, as shown in FIG. **8**, in the forward connected state, the first detent mechanism **45** releases engagement with the first clutch piston **35**. In other words, the first engagement member **52** rides over the first step portion **353**, and contacts the second flat portion **354**. Moreover, the second engagement member **54** rides over the second step portion **356**, and contacts the fourth flat portion **357**. Due to this configuration, the first engagement member **52** and the second engagement member **54** do not push the first clutch piston **35** along the propeller shaft axial direction, so that the inner first clutch plates **34** and the outer first clutch plates **33** of the forward clutch **31** are mutually disengaged. Due to this configuration, the forward clutch **31** is put into the disconnected state.

Furthermore, in the forward connected state, the second detent mechanism **46** is disengaged from the second clutch piston **39**. In other words, the first engagement member **62** of the second detent mechanism **46** is removed from the first step portion **393**, and also the second engagement member **64** is removed from the second step portion **396**. Accordingly, the first engagement member **62** does not push upon the first step portion **393**, and the second engagement member **64** does not push upon the second step portion **396**. Due to this configuration, the reverse clutch **32** remains in the disconnected state.

As has been explained above, in the forward connected state, the connection changeover mechanism **28** puts the dog clutch **26** and the forward gear **22** into the connected state, and also puts the forward clutch **31** into the disconnected state. Moreover, in the forward connected state, the connection changeover mechanism **28** puts the dog clutch **26** and the reverse gear **23** into the disconnected state, and also puts the reverse clutch **32** into the disconnected state. Accordingly, in the forward connected state, the rotation of the drive shaft **11** is transmitted to the propeller shaft **14** via the forward gear **22** and the dog clutch **26**.

Yet further, by the shift shaft **41** shifting from its neutral position in the reverse shifting direction, which is opposite to the forward shifting direction, the system shifts from the neutral position to a reverse connection position via a reverse intermediate position. The reverse intermediate position is positioned between the neutral position and the reverse connection position. FIG. **9** shows the shifting mechanism **15** in a state in which the shift shaft **41** is positioned at its reverse intermediate position (hereinafter this will be termed the "reverse synchronizing state"). And FIG. **10** shows the shifting mechanism **15** in a state in which the shift shaft **41** is positioned at its reverse connection position (hereinafter this will be termed the "reverse connected state").

As shown in FIG. **9**, in the reverse synchronizing state, in a similar manner to the case with the forward synchronizing state, the dog clutch **26** is disconnected both from the forward gear **22** and from the reverse gear **23**. Moreover, in the reverse synchronizing state, the second detent mechanism is engaged to the second clutch piston **39**. Due to this configuration, the reverse clutch **32** is put into the connected state. Moreover, in the reverse synchronizing state, the first detent mechanism **45** is disengaged from the first clutch piston **35**. Due to this configuration, the forward clutch **31** is maintained in the disconnected state.

As described above, in the reverse synchronizing state, the connection changeover mechanism **28** puts the dog clutch **26** and the reverse gear **23** into the disconnected state, and puts the reverse clutch **32** into the connected state. Moreover, in the reverse synchronizing state, the connection changeover mechanism **28** puts the dog clutch **26** and the forward gear **22** into the disconnected state, and also puts the forward clutch **31** into the disconnected state. Accordingly, in the reverse synchronizing state, the rotation of the drive shaft is transmitted to the propeller shaft **14** via the reverse clutch **32**. Due to this configuration, the reverse gear **23** and the dog clutch **26** are synchronized by the dog clutch **26** rotating along with the propeller shaft **14**.

When the shift shaft **41** is further driven from the reverse intermediate position in the reverse shifting direction, and the load exerted from the second detent mechanism **46** upon the second clutch piston **39** becomes greater than a predetermined value, the first engagement member **62** of the second detent mechanism **46** shifts radially inward of the shift shaft **41** against the resistance of the elastic force of the first elastic member **63** which is overcome. Moreover, the second engagement member **64** shifts radially inward of the shift shaft **41** against the resistance of the elastic force of the second elastic member **65** which is overcome. Due to this configuration, the first engagement member **62** rides over the first step portion **393** and shifts in the reverse shifting direction. Moreover, the second engagement member **64** rides over the second step portion **396** and shifts in the reverse shifting direction. As a result, the shifting mechanism **15** transitions into the reverse connected state shown in FIG. **10**.

In the reverse connected state, the reverse dog portion **263** of the dog clutch **26** is meshed with the dog portion **235** of the reverse gear **23**. Moreover, the forward dog portion **262** of the dog clutch **26** is removed from the dog portion **225** of the forward gear **22**. Accordingly, the dog clutch **26** is connected to the reverse gear **23** and is disconnected from the forward gear **22**.

Furthermore, in the reverse connected state, the second detent mechanism **46** is disengaged from the second clutch piston **39**. Due to this configuration, the reverse clutch **32** is put into the disconnected state. Moreover, in the reverse connected state, the first detent mechanism **45** is disconnected from the first clutch piston **35**. Due to this configuration, the forward clutch **31** remains in the disconnected state.

As described above, in the reverse connected state, the connection changeover mechanism **28** puts the dog clutch **26** and the reverse gear **23** into the connected state, and puts the reverse clutch **32** into the disconnected state. Moreover, in the reverse connected state, the connection changeover mechanism **28** puts the dog clutch **26** and the forward gear **22** into the disconnected state, and also puts the forward clutch **31** into the disconnected state. Accordingly, in the reverse connected state, the rotation of the drive shaft **11** is transmitted to the propeller shaft **14** via the reverse gear **23** and the dog clutch **26**.

Next, the control system of the outboard motor **1** will be explained. FIG. **11** is a block diagram showing the control system of the outboard motor **1**. The outboard motor **1** includes a shift operating member **71**, a position detection unit **72**, and a control unit **73**. The shift operating member **71** is configured to be operated to a neutral operating position "N", a forward operating position "F", and a reverse operating position "R". A detection signal specifying the operating position of the shift operating member **71** is inputted to the control unit **73**.

The position detection unit **72** continuously detects the position of the shift shaft **41**. A detection signal that specifies the operating position of the shift shaft **41** is inputted to the control unit **73**. For example, the position detection unit **72** may detect the position in the vertical direction of the transmission shaft **43** by detecting the rotational angle of the axis of a motor within the actuator **42**. The control unit **73** is configured or programmed to determine the front-back position of the shift shaft **41** from the value of the position in the vertical direction of the transmission shaft **43**.

The control unit **73** includes a calculation device such as a CPU or the like, and storage devices such as RAM and ROM and so on. The control unit **73** is configured or programmed to perform electronic control of the actuator **42** according to the operating position of the shift operating member **71** and the position of the shift shaft **41**. The control unit **73** inputs a command signal to the actuator **42**. The drive force of the actuator **42** changes according to this command signal. The control unit **73** is configured or programmed to execute synchronization control before the shifting stage in which the dog clutch **26** and the forward gear **22** or the reverse gear **23** mesh together. In the following, this synchronization control will be explained for the forward shifting case in which the dog clutch **26** and the forward gear **22** mesh together.

During forward shifting, the control unit **73** is configured or programmed to control the actuator **42**, and to shift the shaft **41** from the neutral position to the forward intermediate position. Due to this configuration, the inner first clutch plates **34** and the outer first clutch plates **33** of the forward clutch **31** are contacted together, and the rotational speed of the forward gear **22** and the rotational speed of the dog clutch **26** are synchronized together. FIG. **12** is a timing chart showing the synchronization control during forward shifting.

The broken line in FIG. **12**(A) shows the change of the rotational speed of the forward gear **22**. It will be assumed that the rotational speed of the forward gear **22** is constant at an idling rotational speed R_{IDL}. The solid line in FIG. **12**(A) shows the change of the rotational speed of the propeller **12**. FIG. **12**(B) shows the change of the position of the shift shaft **41**. FIG. **12**(C) shows the change of the command voltage value sent to the actuator **42**.

At the time point t**0**, the shift operating member **71** is positioned at the neutral operating position "N". Accordingly, as shown in FIG. **12**(C), the command voltage value to the actuator **42** is 0, and the actuator **42** is not being driven. Moreover, as shown in FIG. **12**(B), the shift shaft **41** is positioned at the neutral position "N". Furthermore, as shown in FIG. **12**(A), the rotational speed of the propeller is 0.

When the shift operating member **71** is operated from the neutral operating position "N" to the forward operating position "F", the control unit **73** controls the actuator **42** so that the shift shaft **41** shifts from the neutral position "N" to a second target position "F2" via a first target position "F1". In the synchronization control for forward shifting, the first target position "F**1**" is the forward intermediate position described above. The second target position "F**2**" is the forward connection position described above. The control unit **73** controls the actuator **42** by feedback control on the basis of the detection signal from the position detection unit **72**, so that the shift shaft **41** shifts to the first target position "F**1**" and then to the second target position "F**2**".

In detail, first, between the time point t**0** and the time point t**1**, the control unit **73** inputs a command signal having a third command value V**3** to the actuator **42**. Due to this, the shift shaft **41** shifts from its neutral position "N" toward the first target position "F**1**". The third command value V**3** is a fixed value. In the present preferred embodiment, the third command value V**3** is the maximum voltage value for the actuator **42**. However, the third command value V**3** could also be less than this maximum voltage value. Moreover, the third command value is not limited to being a fixed value; it could also be variable.

At the time point t**1**, the connection of the forward clutch **31** is started. In other words, the contacting between the inner first clutch plates **34** and the outer first clutch plates **33** of the forward clutch **31** is started at the time point t**1**. It should be understood that, directly before the time point t**1**, the control unit **73** decreases the command value for the actuator **42**. Due to this configuration, overshooting of the first target position "F**1**" is prevented by decelerating the shift shaft **41**.

From the time point t**1** until the time point t**2**, the control unit **73** executes synchronization control so as to position the shift shaft **41** at the first target position "F**1**" by inputting a command signal having a first command value V**1** to the actuator **42**. The first command value V**1** is smaller than the third command value V**3**. The first command value V**1** is a fixed value. However, the first command value V**1** is not limited to being a fixed value; it could also be variable.

In the synchronization control, the control unit **73** holds the command value to the actuator **42** at the first command value V**1** for a predetermined time period. Due to this, the contacting state between the inner first clutch plates **34** and the outer first clutch plates **33** of the forward clutch **31** is maintained. In other words, during the predetermined time period, the frictional force between the inner first clutch plates **34** and the outer first clutch plates **33** of the forward clutch **31** is kept constant.

As shown in FIG. **12**(A), between the time point t**1** and the time point t**2**, due to the above synchronization control, the rotational speed of the propeller gradually increases. Due to this, the difference between the rotational speed of the forward gear **22** and the rotational speed of the propeller **12** decreases.

It should be understood that the predetermined time period is the time period until the difference between the rotational speed of the propeller **12** and the rotational speed of the forward gear **22** reaches an equilibrium state. In other words, the predetermined time period is the time period until the difference between the rotational speed of the propeller shaft **14** and the rotational speed of the drive shaft **11** reaches an equilibrium state. The term "equilibrium state" means a state in which, due to a balance between the force of resistance upon the propeller **12** from the water and the frictional force of the forward clutch **31**, the difference between the rotational speed of the propeller shaft **14** and the rotational speed of the forward gear **22** almost does not change. In the present preferred embodiment, the predetermined time period is fixed. For example, the predetermined time period is preferably set in advance to the time period required for the rotational speed of the propeller shaft **14** to reach a predetermined threshold value that is, for example, about 70% or greater and about 80% or less of the rotational speed of the forward gear **22**. However, the predetermined time period is not limited to being fixed; it could also be variable.

Next, between the time point t**2** and the time point t**3**, by inputting a command signal having a second command value V**2** to the actuator **42**, the control unit **73** causes the shift shaft **41** to shift from the first target position "F**1**" to the second target position "F**2**". The second command value V**2** is greater than the first command value V**1**. The second command value V**2** is a fixed value. In the present preferred embodiment, the second command value V**2** is the maximum voltage value for the actuator **42**. However, it would also be acceptable for the second command value V**2** to be smaller than the maximum voltage value. Moreover, the second command value V**2** is not limited to being fixed; it could also be variable.

When, in the interval between the time point t**2** and the time point t**3**, the shift shaft **41** arrives at the second target position "F**2**", the forward gear **22** and the dog clutch **26** mesh together. At this time, the forward gear **22** and the dog clutch **26** mesh together smoothly, since the difference between the rotational speed of the forward gear **22** and the rotational speed of the dog clutch **26** has become small due to the synchronization control described above.

Thereafter, at the time point t**3**, the control unit **73** sets the command value for the actuator **42** to zero. Due to this the shift shaft **41** stops, and forward shifting is completed. It should be understood that, directly before the time point t**3**, the control unit **73** decreases the command value for the actuator **42**. Due to this, by decelerating the shift shaft **41**, it is possible to stop the shift shaft **41** rapidly.

During reverse shifting in which the dog clutch **26** and the reverse gear **23** mesh together as well, similar synchronization control is performed to the forward shifting described above. During reverse shifting, the first target position "F**1**" is the reverse intermediate position described above. The second target position "F**2**" is the reverse connection position described above. The control unit **73** is configured or programmed to control the actuator **42** by feedback control on the basis of the detection signal from the position detection unit **72**, so that the shift shaft **41** shifts to the first target position "F**1**" and then to the second target position "F**2**". The command values for the actuator **42** during reverse shifting are the same as the command values during forward shifting, except for the fact that positive and negative are interchanged. Accordingly, detailed explanation of the control during reverse shifting will be omitted.

It should be understood that the neutral position, the forward intermediate position, and the reverse intermediate position of the shift shaft **41** described above may experience some influence from the accuracies of the various components. Accordingly, it is more desirable to set the value of each of these positions to an intrinsic value for each individual outboard motor **1**, rather than setting all of them uniformly in advance for all outboard motors **1**. In the following, a method of calibrating the target positions of the shift shaft **41** will be explained on the basis of FIG. **13**.

First, in a step S**1**, the forward intermediate position is determined. Here, the control unit **73** controls the actuator **42**, and drives the shift shaft **41** in the forward shifting direction. At this time, the command value for the actuator **42** is set in advance to a value such that, when the voltage and the temperature of the actuator **42** are in a standard state, a predetermined target pressing force is obtained for the forward clutch **31**. For example, the command value for the actuator **42** may be set to the first command value V**1** described above. The control unit **73** stores the position where the shift shaft **41** has stopped in a storage device as the forward intermediate position.

Next, in a step S**2**, the reverse intermediate position is determined. Here, the control unit **73** is configured or programmed to control the actuator **42**, and to drive the shift shaft **41** in the reverse shifting direction. At this time, the command value for the actuator **42** is set in advance to a value such that, when the voltage and the temperature of the actuator **42** are in a standard state, a predetermined target pressing force is obtained for the reverse clutch **32**. For example, the command value for the actuator **42** may be set to the value (−V**1**) obtained by negating the first command value V**1** described above. The control unit **73** stores the position where the shift shaft **41** has stopped in the storage device as the reverse intermediate position.

Next, in a step S**3**, the neutral position is determined. Here, the control unit **73** is configured or programmed to determine the average value of the forward intermediate position that was determined in the step S**1** and the reverse intermediate position that was determined in the step S**2** as being the neutral position.

According to the preferred embodiments described above, by the control unit **73** controlling the actuator **42**, it is possible to perform synchronization control whose accuracy is high with the friction clutches **31** and **32**. Due to this configuration, it is possible to significantly reduce or prevent shift shock with a simple operation.

During synchronization control for forward shifting, the control unit **73** controls the actuator **42** so as to maintain the contacting state of the outer first clutch plates **33** and the inner first clutch plates **34** during the predetermined time period. The actuator **42** is controlled so that the frictional force between the outer first clutch plates **33** and the inner first clutch plates **34** remains constant. Due to this, it is possible to synchronize the forward gear **22** and the dog clutch **26** in a reliable manner.

Moreover, during synchronization control for reverse shifting, the control unit **73** controls the actuator **42** so as to maintain the contacting state of the outer second clutch plates **37** and the inner second clutch plates **38** during the predetermined time period. The actuator **42** is controlled so that the frictional force between the outer second clutch plates **37** and the inner second clutch plates **38** remains constant. Due to this, it is possible to synchronize the reverse gear **23** and the dog clutch **26** in a stable manner.

The predetermined time period is the time period until the difference between the rotational speed of the propeller shaft **14** and the rotational speed of the drive shaft **11** reaches an equilibrium state. Due to this, it is possible to synchronize the rotational speed of the propeller shaft **14** up to the overall upper limits of the transmission capabilities of the friction clutches **31** and **32**. Due to this, it is possible to significantly reduce or prevent the occurrence of shift shock by making the difference between the rotational speed of the propeller shaft **14** and the rotational speed of the drive shaft **11** small.

The predetermined time period is preferably the time period until the rotational speed of the propeller shaft **14** reaches a predetermined threshold value that is, for example, greater than or equal to about 70% of the rotational speed of the drive shaft **11**, and, moreover is less than or equal to about 80% thereof. Due to this, it is possible to significantly reduce or prevent the occurrence of shift shock more effectively, as compared with the case when the rotational speed of the propeller shaft **14** during synchronization is about 20% to about 30% of the rotational speed of the drive shaft **11**. Moreover, it is possible to use friction clutches **31** and **32** whose transmission capabilities are smaller, as compared with the case in which the predetermined time period is the time period required for the rotational speed of the propeller shaft **14** to become the same as the rotational speed of the drive shaft **11**. Due to this configuration, it is possible to make the friction clutches **31** and **32** more compact.

The control unit **73** controls the actuator **42** by feedback control on the basis of the detection signal from the position detection unit **72**, so that the shift shaft **41** shifts to its first target position "F**1**" and then to its second target position "F**2**". Due to this, it is possible to execute synchronization control at high accuracy.

During synchronization control, the control unit **73** inputs a command signal including the first command value V**1** to the actuator **42**, while in the shifting stage the control unit **73** inputs a command signal including the second command value V**2** to the actuator **42**. The first command value V**1** is smaller than the second command value V**2**. Accordingly, during synchronization control, the actuator **42** drives the shift shaft **41** with a smaller drive force than during the shifting stage. Due to this, it is possible to significantly reduce or prevent the occurrence of shift shock. To put the matter conversely, the second command value V**2** for the shifting stage is greater than the first command value V**1** during synchronization control. Due to this, it is possible to complete the shifting process rapidly.

The control unit **73** causes the shift shaft **41** to shift from the neutral position "N" to the first target position "F**1**" by inputting a command signal including the third command value V**3** to the actuator **42**. The third command value V**3** is larger than the first command value V**1**. Due to this, it is possible to rapidly shift the shift shaft **41** from the neutral position "N" to the first target position "F**1**".

Although preferred embodiments of the present invention have been disclosed and explained above, the present invention is not to be considered as being limited to these preferred embodiments; various alterations are possible without deviating from the scope and the gist of the present invention.

For example, the reverse clutch **32** could be omitted. In other words, it would be acceptable only to perform synchronization with the forward clutch **31**.

The friction clutches **31** and **32** are not limited to being multi plate type clutches; they could be clutches of some other type, such as single plate type clutches or the like.

The structure of the connection changeover mechanism **28** is not limited to being a structure that employs the sliding shaft **41**, the first detent mechanism **45**, and the second detent mechanism **46** as described above; it could be altered in various ways.

In the preferred embodiments described above, the control unit **73** is preferably configured or programmed to perform feedback control of the actuator **42** on the basis of the detection signal from the position detection unit **72**. However, the control of the actuator **42** is not limited to being positional control; some other control method could be employed. For example, FIG. **14** is a block diagram showing a control system according to a variant preferred embodiment. As shown in FIG. **14**, the outboard motor **1** is equipped with a current detection unit **74**. The current detection unit **74** continuously measures the current in the actuator **42**. The drive force of the actuator **42** changes according to the value of the current in the actuator **42**. The control unit **73** is preferably configured or programmed to control the actuator **42** by feedback control on the basis of the detection signal from the current detection unit **74**. With the control system according to this variant preferred embodiment, the command value described above is a command value for the current for the actuator **42**.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

1. An outboard motor comprising:

an engine;

a drive shaft extending downward from the engine;

a drive gear fixed to the drive shaft;

a propeller shaft extending in a direction that intersects the drive shaft;

a forward gear meshed with the drive gear;

a reverse gear meshed with the drive gear;

a shift operating member that is operated to change between forward and reverse;

a dog clutch disposed on the propeller shaft, the dog clutch changing between connecting the forward gear to the propeller shaft and connecting the reverse gear to the propeller shaft by selectively meshing with the forward gear or the reverse gear according to an operation of the shift operating member;

a friction clutch including a first friction surface that transmits rotation of the drive shaft, and a second friction surface that transmits rotation of the propeller shaft, the friction clutch transmitting rotation of the drive shaft to the propeller shaft by the first friction surface and the second friction surface contacting together;

an actuator that drives the friction clutch; and

a controller configured or programmed, before a shifting stage in which the dog clutch meshes with the forward gear or with the reverse gear, to execute synchronization control by controlling the actuator to contact the first friction surface and the second friction surface of the friction clutch together; wherein

in the synchronization control, the controller is configured or programmed to control the actuator so as to maintain a contacting state between the first friction surface and the second friction surface during a predetermined time period.

2. The outboard motor according to claim **1**, wherein the controller is configured or programmed to control the actuator so as to keep a frictional force between the first friction surface and the second friction surface constant during the predetermined time period.

3. The outboard motor according to claim **1**, wherein the predetermined time period is a time period that it takes for a difference between a rotational speed of the propeller shaft and a rotational speed of the drive shaft to reach an equilibrium state.

4. The outboard motor according to claim **1**, wherein the predetermined time period is a time period that it takes for a rotational speed of the propeller shaft to reach a predetermined threshold value that is between about 70% and about 80% of a rotational speed of the drive shaft.

5. An outboard motor comprising:

an engine;

a drive shaft extending downward from the engine;

a drive gear fixed to the drive shaft;

a propeller shaft extending in a direction that intersects the drive shaft;

a forward gear meshed with the drive gear;

a reverse gear meshed with the drive gear;

a shift operating member that is operated to change between forward and reverse:

a dog clutch disposed on the propeller shaft, the dog clutch changing between connecting the forward gear to the propeller shaft and connecting the reverse gear to the propeller shaft by selectively meshing with the forward gear or the reverse gear according to an operation of the shift operating member;

a friction clutch including a first friction surface that transmits rotation of the drive shaft, and a second friction surface that transmits rotation of the propeller shaft, the friction clutch transmitting rotation of the drive shaft to the propeller shaft by the first friction surface and the second friction surface contacting together;

an actuator that drives the friction clutch;

a controller configured or programmed, before a shifting stage in which the dog clutch meshes with the forward gear or with the reverse gear, to execute synchronization control by controlling the actuator to contact the first friction surface and the second friction surface of the friction clutch together; and

a shift shaft that transmits operation of the actuator to the dog clutch and to the friction clutch; wherein

the shift shaft shifts to a first target position and to a second target position;

contact between the first friction surface and the second friction surface starts in a state in which the shift shaft is positioned at the first target position;

the dog clutch and the forward gear mesh together in a state in which the shift shaft is positioned at the second target position; and

the controller is configured or programmed to control the actuator so that the shift shaft shifts to the first target position and then to the second target position.

6. The outboard motor according to claim **5**, further comprising:

a position detector that detects a position of the shift shaft; wherein

the controller is configured or programmed to control the actuator by feedback control based on a detection signal from the position detector, so that the shift shaft shifts to the first target position and then to the second target position.

7. An outboard motor comprising:

an engine;

a drive shaft extending downward from the engine;

a drive gear fixed to the drive shaft;

a propeller shaft extending in a direction that intersects the drive shaft;

a forward gear meshed with the drive gear;

a reverse gear meshed with the drive gear;

a shift operating member that is operated to change between forward and reverse;

a dog clutch disposed on the propeller shaft, the dog clutch changing between connecting the forward gear to the propeller shaft and connecting the reverse gear to the propeller shaft by selectively meshing with the forward gear or the reverse gear according to an operation of the shift operating member;

a friction clutch including a first friction surface that transmits rotation of the drive shaft, and a second friction surface that transmits rotation of the propeller shaft, the friction clutch transmitting rotation of the drive shaft to the propeller shaft by the first friction surface and the second friction surface contacting together;

an actuator that drives the friction clutch; and

a controller configured or programmed, before a shifting stage in which the dog clutch meshes with the forward gear or with the reverse gear, to execute synchronization control by controlling the actuator to contact the first friction surface and the second friction surface of the friction clutch together; wherein

the controller is configured or programmed to input a command signal to the actuator according to a drive force of the actuator;

during the synchronization control, the controller is configured or programmed to input to the actuator a command signal including a first command value; and

in the shifting stage, the controller is configured or programmed to input to the actuator a command signal including a second command value that is different from the first command value.

8. The outboard motor according to claim **7**, wherein the first command value is smaller than the second command value.

9. The outboard motor according to claim **8**, wherein the first command value is a fixed value.

10. An outboard motor comprising:

an engine;

a drive shaft extending downward from the engine;

a drive gear fixed to the drive shaft;
a propeller shaft extending in a direction that intersects the drive shaft;
a forward gear meshed with the drive gear;
a reverse gear meshed with the drive gear;
a shift operating member that is operated to change between forward and reverse;
a dog clutch disposed on the propeller shaft, the dog clutch changing between connecting the forward gear to the propeller shaft and connecting the reverse gear to the propeller shaft by selectively meshing with the forward gear or the reverse gear according to an operation of the shift operating member;
a friction clutch including a first friction surface that transmits rotation of the drive shaft, and a second friction surface that transmits rotation of the propeller shaft, the friction clutch transmitting rotation of the drive shaft to the propeller shaft by the first friction surface and the second friction surface contacting together;
an actuator that drives the friction clutch;
a controller configured or programmed, before a shifting stage in which the dog clutch meshes with the forward gear or with the reverse gear, to execute synchronization control by controlling the actuator to contact the first friction surface and the second friction surface of the friction clutch together; and
a shift shaft that transmits operation of the actuator to the dog clutch and to the friction clutch; wherein
the shift shaft shifts to a neutral position, to a first target position, and to a second target position;
in a state in which the shift shaft is positioned at the neutral position, the first friction surface and the second friction surface are not in contact, and the dog clutch and the forward gear are not meshed together;
contact between the first friction surface and the second friction surface starts in a state in which the shift shaft is positioned at the first target position;
the dog clutch and the forward gear mesh together in a state in which the shift shaft is positioned at the second target position;
the controller is configured or programmed to control the actuator so that the shift shaft shifts to the neutral position, to the first target position, and to the second target position;
the controller is configured or programmed to shift the shift shaft from the neutral position towards the first target position by inputting to the actuator a command signal including a third command value;
the controller is configured or programmed to execute the synchronization control to position the shift shaft to the first target position by inputting to the actuator a command signal including a first command value which is smaller than the third command value; and
the controller is configured or programmed to shift the shift shaft from the first target position towards the second target position by inputting to the actuator a command signal including a second command value which is greater than the first command value.

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